

AD-A165 620

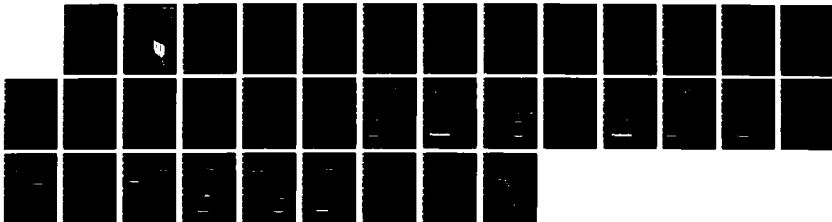
INITIAL INVESTIGATION OF THREE UNCURED ELASTOMERIC
ROOFING MEMBRANE MATER. (U) CONSTRUCTION ENGINEERING
RESEARCH LAB (ARMY) CHAMPAIGN IL M J ROSENFELD FEB 86
CERL-IR-M-86/83

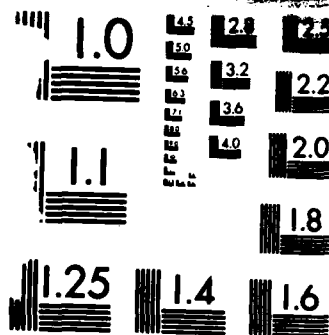
1/1

UNCLASSIFIED

F/G 13/13

NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



US Army Corps
of Engineers

Construction Engineering
Research Laboratory

USA-CERL

INTERIM REPORT M-86/03

February 1986

Improved and New Roofing for
Military Construction

②

Initial Investigation of Three Uncured Elastomeric Roofing Membrane Materials for Use in Military Construction

by
Myer J. Rosenfield

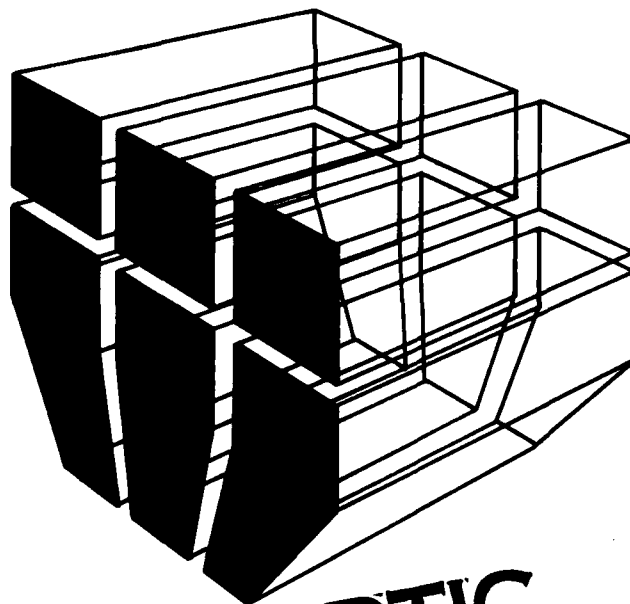
Three uncured elastomeric membranes were investigated as part of ongoing research into alternative roofing systems for military construction. Literature, manufacturers' data, and field applications were investigated to identify the properties and characteristics of chlorinated polyethylene (CPE), chloro-sulfonated polyethylene (CSPE), and polyisobutylene (PIB), and the advantages and disadvantages associated with their use.

It was concluded that Corps of Engineers use of these three materials should not be considered until an industry-wide standard for their manufacture is developed. In addition, results of future work which will test actual roofing applications should be considered before a final decision is made.

Keywords: Installation, roofing, High Strength

DTIC FILE COPY

Approved for public release; distribution unlimited.



DTIC
ELECTE
MAR 14 1986
S E D

86 3 14 051

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official indorsement or approval of the use of such commercial products. The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

***DESTROY THIS REPORT WHEN IT IS NO LONGER NEEDED
DO NOT RETURN IT TO THE ORIGINATOR***

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CERL IR M-86/03	2. GOVT ACCESSION NO. AD-A165 620	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) INITIAL INVESTIGATION OF THREE UNCURED ELASTOMERIC ROOFING MEMBRANE MATERIALS FOR USE IN MILITARY CONSTRUCTION		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Myer J. Rosenfield		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Construction Engr Research Laboratory P.O. Box 4005 Champaign, IL 61820-1305		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 4A162731AT41-A-044
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE February 1986
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 32
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Copies are available from the National Technical Information Service Springfield, VA 22161		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) roofs elastomers elastomeric membranes		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Three uncured elastomeric membranes were investigated as part of ongoing research into alternative roofing systems for military construction. Literature, manufacturers' data, and field applications were investigated to identify the properties and characteristics of chlorinated polyethylene (CPE), chlorosulfonated polyethylene (CSPE), and polyisobutylene (PIB), and the advantages and disadvantages associated with their use.		

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

BLOCK 20 (Cont'd)

It was concluded that Corps of Engineers use of these three materials should not be considered until an industry-wide standard for their manufacture is developed. In addition, results of future work which will test actual roofing applications should be considered before a final decision is made.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

FOREWORD

This research is being conducted for the Office of the Assistant Chief of Engineers (OACE) under Project 4A162731AT41, "Military Facilities Engineering Technology"; Technical Area A; "Facility Planning and Design"; Work Unit 044, "Improved and New Roofing for Military Construction." The OACE Technical Monitor is Mr. Chester Kirk, DAEN-ZCF-B.

The work is being done by the Engineering and Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (USA-CERL). Appreciation is expressed to Mr. Daniel Kane for his assistance in gathering the information for this report by visiting the manufacturers and observing roofs under construction and completed.

Dr. Robert Quattrone is Chief of USA-CERL-EM, Dr. L. R. Shaffer is Technical Director, and COL Paul J. Theuer is Commander and Director.

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution	
Availability Codes	
Dist	Avail. and/or Special
A-1	



CONTENTS

	Page
DD FORM 1473	1
FOREWORD	3
LIST OF TABLES AND FIGURES	4
1 INTRODUCTION	7
Background	
Objective	
Approach	
Mode of Technology Transfer	
2 DEVELOPMENT OF UNCURED ELASTOMERIC ROOFING MEMBRANES . .	7
History	
Manufacture	
Properties	
3 ADVANTAGES AND DISADVANTAGES.	11
Advantages	
Disadvantages	
4 INSTALLATION METHODS	12
Loose-Laid and Ballasted	
Mechanically Fastened	
Partially Adhered	
Fully Adhered	
5 USING UNCURED ELASTOMERIC SYSTEMS	13
Reroofing	
New Construction	
Flashing and Sealing	
Insulation Restrictions	
Repair Methods	
6 CONCLUSIONS AND RECOMMENDATIONS	16
REFERENCES	17
APPENDIX: Manufacturers' Details	18
DISTRIBUTION	

TABLES

Number	Page
1 Comparison of Physical and Mechanical Properties	9

FIGURES

A1 Typical Gravel Stops	19
A2 Joints in Gravel Stops	20
A3 Base Flashings at Walls	21
A4 Base Flashings at Parapets	22
A5 Wall Scuppers	23
A6 Gutters	24
A7 Typical Butt Joints	25
A8 Roof Drains	26
A9 Vent Pipes	27
A10 Curb Flashings	28
A11 Expansion Joints -- Roof	29
A12 Expansion Joints -- Roof to Wall	30
A13 Pitch Pockets	31
A14 Walkways	32

INITIAL INVESTIGATION OF THREE UNCURED ELASTOMERIC ROOFING MEMBRANE MATERIALS FOR USE IN MILITARY CONSTRUCTION

1 INTRODUCTION

Background

Most Army facilities use conventional roofing systems, such as built-up roofing (BUR), that are sometimes expensive and complicated to construct. These conventional roofing systems are often comparatively short-lived, resulting in high life-cycle roofing costs which are difficult for already overburdened Army operation and maintenance budgets to absorb. The Office of the Chief of Engineers has asked the U.S. Army Construction Engineering Research Laboratory (USA-CERL) to identify alternative roofing systems that can improve the performance of Army roofing while reducing life-cycle costs. This involves (1) evaluating innovative roofing systems and materials to determine alternatives to BUR, (2) providing a means to improve Army roof performance and reduce life-cycle costs, (3) improving contractor quality control (CQC) of BUR construction, and (4) developing or improving guide specifications for selected alternative systems.

Previous work included an overview of alternative reroofing systems,¹ and discussions of polyvinyl chloride (PVC) single-ply systems² and sprayed polyurethane foam with protective coatings.³

Objective

The objective of this report is to document one phase of an investigation into the possible use of three uncured elastomeric membrane materials in military construction: chlorinated polyethylene (CPE); chlorosulfonated polyethylene (CSPE), commonly referred to as "Hypalon";* and polyisobutylene (PIB). (Although

there are other uncured elastomers on the market, such as ethylene vinyl acetate (EVA), silicone, and butadiene-acrylonitrile (NBP), their impact on the market is very slight at present.)

Approach

This investigation is being conducted in the following steps:

1. Survey of literature, manufacturers, and field applications to identify the properties and characteristics of uncured elastomeric roofing membranes and the advantages and disadvantages associated with their use.
2. Construction of representative roofing systems at selected Army installations, or small-scale exposure tests before committing to actual roof construction.
3. Evaluation of the design, construction and post-construction performance of the test roofs, in order to determine the suitability of uncured elastomers for use in Army roofing systems and the subsequent preparation of appropriate Corps of Engineers Guide Specifications (CEGS).

This report documents step 1, above.

Mode of Technology Transfer

If the results of this study show that uncured elastomeric roofing can be used at Army installations, it will be recommended that a group of guide specifications for their use be included in the CEGS series 07000.

2 DEVELOPMENT OF UNCURED ELASTOMERIC ROOFING MEMBRANES

History

PIB was first used in Europe in 1950 and in the United States in 1977. CSPE was first used in Europe in 1963 and in the United States in 1976. CPE dates back only to 1973 in Europe and 1978 in the United States. Each product is marketed in this country by several different companies, some under licensing agreements for manufacture and distribution. The number of such companies has varied over the years as new ones have entered the market and others have dropped out. In at least one instance, the product manufactured by one company is also marketed by other companies under different trade names.

¹E. Marvin, et al., *Evaluation of Alternative Reroofing Systems*, Interim Report M-263/ADA071578 (USA-CERL, June 1979).

²M. J. Rosenfield, *An Evaluation of Polyvinyl Chloride (PVC) Single-Ply Membrane Roofing Systems*, Technical Report M-284/ADA097931 (USA-CERL, March 1981).

³M. J. Rosenfield, *Evaluation of Sprayed Polyurethane Foam Roofing and Protective Coatings*, Technical Report M-297/ADA109696 (USA-CERL, November 1981).

*"Hypalon" is a registered trademark of E.I. DuPont de Nemours and Company.

Manufacture

CPE and CSPE are produced as basic resins and formulated by different membrane manufacturers according to their own specifications. For roofing materials, the U.S. producer of CPE resin is Dow Chemical Company, while the producer of CSPE resin is DuPont. PIB is manufactured in this country by AGR Company, a joint venture between Braas and Company, GmbH, of Frankfort, West Germany (the developer), and Republic Powdered Metals (RPM) of Medina, OH.

Within the rubber industry, CPE and CSPE are termed CM and CSM, respectively, where the "M" refers to a saturated chain of the polymethylene type, as stated in ASTM D 1418.⁴ This is also the true significance of the "M" in EPDM, a cured elastomer commonly but incorrectly called Ethylene Propylene Diene Monomer.

Most CPE and CSPE membranes are reinforced, and are manufactured similarly by the various producers. This consists essentially of compounding the basic material, extruding or otherwise applying it onto both sides of the reinforcing fabric, and heating between rolls to bond the entire assembly together. These systems are intended to be mechanically fastened. CSPE membranes can also consist of a nonreinforced polymer sheet bonded to a mineral fiber backing. This product is intended to be installed fully adhered, using a water-based latex adhesive.

An important difference between these materials and PVC is the claim that CPE and CSPE do not require the addition of plasticizers to impart elastomeric properties and flexibility. Independent laboratory tests, however, have shown that there could be between 8 and 9 percent by weight of chlorinated wax and dialkyl phthalates, both of which are considered plasticizers.⁵

One manufacturer also produces a hybrid sheet, consisting of a layer of CSPE on one side of the fabric and a layer of CPE on the other side. This material is installed with the CSPE side exposed to the weather.

The PIB is basically a blend of polyethylene and isobutylene in approximately equal proportions,

compounded with carbon black and other additives to aid in processing and impart the desired properties. After compounding and mixing, the molten material is extruded, the nonwoven fiber backing is applied, the guidelines are painted on, and the product is rolled for shipment, all without any tension being applied to the material. The manufacturer states that the fleece serves as a reinforcement as well as a backing material.

The manufacturing processes by which these membrane materials are produced can result in variations in the quality of the membrane which can affect the use of the material. These include variations in material thickness and unit weight, intraply and interply blistering, the presence of and variations in plasticizer content, and the presence of pinholes caused by broken air bubbles.⁶

Properties

To be successful as a roofing membrane, a material must retain its properties over a wide range of temperatures and other ambient conditions; i.e., it should remain resilient and elastomeric from subarctic to subtropical climates, and be able to withstand long exposure to sunlight, water, snow, ice, wind, and blowing sand. It should have enough tensile strength so that the membrane can resist tensile forces created in it by environmental exposure, and enough tear strength to resist tearing at the fasteners. It should also have elasticity to prevent the buildup of excessive tensile stresses, and should resist attack by common chemicals and solvents. Permanent, watertight membrane seams should be easy to make in the field, and repairs should be easily done if damage occurs after several years of aging. The completed roof should meet Factory Mutual (FM) and Underwriters Laboratories (UL) fire and wind safety requirements.

The physical and mechanical properties of some of the uncured elastomers now on the market for use as roofing membranes are listed in Table 1. The manufacturers contacted during this investigation did not all list the same properties in the same units and did not use the same test methods for all the determinations, so a direct comparison of a given property between different products may not be completely meaningful. In fact, the American Society for Testing and Materials (ASTM) cautions that different tests for a given property may yield different results. At present, none of the manufacturers surveyed has the tests performed by independent testing laboratories.

⁴ASTM D 1418-81, "Rubber and Rubber Latexes - Nomenclature, Practice For" (American Society for Testing and Materials, 1981).

⁵Private communication, M. J. Rosenfield with Simpson, Gumpertz and Heger Inc., May 1985.

⁶Private communication, M. J. Rosenfield with Simpson, Gumpertz and Heger Inc., May 1985.

Table 1
Comparison of Physical and Mechanical Properties

Company* Material Trade Name	Cooley CPE CoolTop 40	Cooley CPE ReinfCPE	Pantasote CPE FLXHD CPE	Conklin CSPE Masterbond	Pantasote CSPE FLXHD HYP	Stevens CSPE Hi-Tuff	Tremco CSPE Trem Ply	Tremco CSPE HP4510	Tremco CSPE HHP	Pantasote CSPE/CPE Hybrid	AGR PIB Alphagard
Attachment	Mechanically Fastened	Loose-Laid Ballasted	Mechanically Fastened	Fully Adhered	Mechanically Fastened	Mechanically Fastened	Fully Adhered	Loose-Laid and Ballasted or Mechanically Fastened	Fully Adhered	Mechanically Fastened	Fully ⁶ Adhered
Reinforcement	Polyester	Polyester	Polyester	None	Polyester	Polyester	None	Polyester	Polyester	Polyester	None
Backing	None	None	None	Fiberglass	None	None	Fleece	None	Fleece	None	Fleece
Wt. Lb/Sq Ft**	0.3	0.22	0.30	0.25	0.31	0.29	0.33	0.45	0.45	0.31	0.57
Sheet Width, In.	62	72	36 & 72	39.5	72	64.5	60	58	58	72	42
Sheet Length, Ft	103.5	85.5	75	82	75	80	120	135	135	75	50
Wt of Roll, Lb	160	113	67 & 135	67	140	125	200	293	293	140	100
Elastomer											
Thickness, Mils	NA ³	NA	NA	20	NA	40	25	38	30	NA	60
Total Thick, Mils	40	32	45	35	45	45	40	45	52	45	100
Tensile Strength	2500 psi	2500 psi	250 lb	1200 psi	250 lb	225 lb	1450 psi	250 lb	250 lb	250 lb	200 lb
Test Method	D 882 ⁴	D 882	D 751	D 412	D 751	D 751	D 412	D 751	D 751	D 751	D 751
Elongation, %	27	27	25	600	25	25	750	25	25	25	70
Test Method	D 751	D 751	D 751	D 412	D 751	D 751	D 412	D 751	D 751	D 751	D 751
Tear Resistance, Lb	60	60	100	NA	100	90	6	95	60	100	30
Test Method	D 2262	D 2262	D 751		D 751	D 751	D 1004	D 751	D 751	D 751	D 751
Seam Strength	95% of TS	95% of TS	80% of TS	NA	80% of TS	180	710 lb/in.	710 lb/in.	710 lb/in.	80% of TS	45 lb/in.
Test Method	D 751	D 751	D 751		D 751	D 751	D 413	D 413	D 413	D 751	D 751
Shrinkage, %	<1	<1	0.5	NA	0.5	0.1	0.5	<1.25	<0.4	0.5	0.5
Test Method	D 1204	D 1204	D 1204		D 1204	D 1204	D 1204	D 1204	D 1204	D 1204	D 1204
Hardness, Shore A	85	85	NA	NA	NA	80	NA	NA	NA	NA	70
Test Method	D 2240	D 2240				D 2240					D 2240
Permeability, Perm-Mils	64.8	51.8	1.8	27.3	1.8	2.2	2	2.25	2.6	1.8	0.9
Test Method	E 96,C	E 96,C	E 96,A	E 96,E	E 96,A	E 96,B	E 96,BW	E 96,BW	E 96,BW	E 96,A	E 96,A
Heat Aging, % TS	100	100	100	103	100	100	100	100	100	100	75
Test Method	D 751	D 751	D 751	D 2707	D 751	D 751	D 573	D 573	D 573	D 751	D 412
Heat Aging, % Elongation	95	95	100	90	100	100	55	100	100	100	75
Test Method	D 838	D 838	D 751	D 2707	D 751	D 751	D 573	D 573	D 573	D 751	D 412
Flexibility, °F	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
Test Method	D 2136	D 2136	D 2136	D 2136	D 2136	D 2136	D 2136	D 1790	D 2136	D 2136	D 2136
Flame Spread, Ft	Pass	Pass	NA	NA	NA	<5	NA	NA	NA	NA	6
Test Method	E 108	E 108				UL 790					E 108
Independent Testing	No ⁵	No	No	No	No	No	No	No	No	No	No
UL Classification ¹	A, C	No	A, C	No	No	A	A	A	A	A	A, B
FM Classification	No ⁵	No	No	No	No	No	No	No	No	No	No
FM Rating, Fire ¹	I	No	I	No	I	I	I	No	No	I	I
FM Rating, Wind	I-90	No	I-60, 90	No	I-90	I-90		I-60, 90		I-90	I-60, 90

*Cooley Roofing Systems, Inc., Pawtucket, RI; Pantasote, Inc., Passaic, NJ; Conklin Company, Inc., Minneapolis, MN; J. P. Stevens and Company, Easthampton, MA; Tremco Roofing Systems, Cleveland, OH; AGR Company, Charlotte, NC.

Notes:

¹ Refer to UL and FM approvals for specific insulations to be used in approved constructions.

² NA: Data are not available from manufacturer.

³ No: UL or FM has not approved the product, or independent laboratory testing has not been performed.

⁴ All test methods are ASTM unless otherwise noted.

⁵ FM has begun to issue A-B-C ratings per ASTM E 108.

⁶ May also be installed loose-laid and ballasted, mechanically fastened, or as a projected membrane.

****Metric conversion factors:**

1 sq ft = 0.093 sq m

1 in. = 25.4 mm

1 lb = 4.535 923 7 x 10⁻¹ kg

1 ft = 0.3048 m

1 mil = 2.54 x 10⁻⁵ m

°F = 1.8 (°C) + 32

The manufacturers listed in Table 1 are not consistent in the test methods used. Two manufacturers of reinforced membranes report all tensile properties on the basis of ASTM D 751.⁷ One manufacturer of reinforced membranes reports tensile strength on the basis of ASTM D 882,⁸ elongation on the basis of ASTM D 751, and tear resistance on the basis of ASTM D 2262.⁹ This manufacturer explains the use of three different test methods as applying to the film and fabric separately, but is retesting for tensile strength and elongation on the basis of ASTM D 751.

Two manufacturers of nonreinforced but backed membranes report tensile properties on the basis of ASTM D 412,¹⁰ while one such manufacturer reports tensile strength and elongation on the basis of ASTM D 882, but tear resistance on the basis of ASTM D 751. It is difficult to understand the rationale behind the use of such divergent test methods. D 751 refers to coated fabrics, D 412 to unreinforced or unbacked rubber, D 882 to unreinforced thin plastic sheeting, and D 2262 to uncoated woven fabric.

In an effort to resolve this confusion, the Single-Ply Roofing Institute (SPRI), an association of manufacturers of single-ply roofing materials, has recently published a guide to specifications.¹¹ The SPRI work has attempted to standardize the basis for determining many of the properties. However, many of the products on the market at the time of this writing are not included in the SPRI publication. The SPRI document does not indicate the construction of the included membranes, so it is not possible directly to correlate the specific membrane with the test method. However, the SPRI document is the first attempt by the single-ply industry to establish industry-wide standards. CEGS for construction rely on industry standards to establish acceptable levels of performance for construction materials. Without such standards, it is difficult to make use of a generic material without being specific, which is not permitted for either new construction or operation and maintenance work.

⁷ASTM D 751-79, "Standard Test Methods of Testing Coated Fabrics" (ASTM, 1979).

⁸ASTM D 882-83, "Standard Test Methods for Tensile Properties of Thin Plastic Sheeting" (ASTM, 1983).

⁹ASTM D 2262-83, "Standard Test Method for Tearing Strength of Woven Fabric by the Tongue (Singler Rip) Method" (ASTM, 1983).

¹⁰ASTM D 412-83, "Standard Test Methods for Rubber Properties in Tension" (ASTM, 1983).

¹¹*Single-Ply Roofing: A Professional's Guide to Specifications* (Single-Ply Roofing Institute, June 1984).

At the time of this writing, the ASTM Subcommittee D08.18 on Non-Bituminous Roofing was nearing completion of its work in drafting a standard for manufacture of uncured elastomeric membranes. Such a document is desirable before the Corps of Engineers can specify this type of material for its use.

3 ADVANTAGES AND DISADVANTAGES

A brief discussion of the advantages and disadvantages of sheet-applied single-ply systems was included in a previous report.¹² A further discussion of the three specific types of uncured elastomers follows.

Advantages

CPE and CSPE are high-strength materials in and of themselves. The reinforcing fabric used with them has approximately the same strengths as the polymers, so the combination provides a balanced system. Elongation, however, is limited to the value of the fabric. Although PIB has lower values for these properties than the other two materials, this does not constitute a problem in its use. No direct correlation has yet been determined between such properties and service.

All three materials have UL Class A, and FM Class I and I-60 or I-90 ratings. Installation can be loose-laid and ballasted, fully adhered, or mechanically fastened. Some can also be installed as protected membrane roofs (PMR). Individual manufacturers should be consulted for their recommended installation methods. One advantage of the PIB is that it does not require a special adhesive for attachment, whether it be fully adhered or only partially attached; type III or IV asphalt serves as an adhesive, and almost all roofing contractors are experienced in its use. However, an adhesive is available for those cases where asphalt cannot be used.

With certain exceptions, the uncured elastomers are resistant to most common chemicals. They are also resistant to ozone and sunlight attack, which allows them to be installed in a wide range of climates and environments. Most re-roofing applications are over existing old, deteriorated built-up roofs, which is contrary to good practice. Many of these old roofs were constructed of coal-tar pitch. While most of the uncured elastomers are resistant to coal-tar, the

¹²E. Marvin, et al.

membrane manufacturers should be consulted as to any precautions that must be observed in these applications. Because they may contain plasticizers, uncured elastomers may harden and become brittle from plasticizer migration and loss with the passage of time.

Disadvantages

Despite the versatility and wide installation possibilities of uncured elastomers, certain environmental exposures must be avoided. CPE is questionable if exposed to nitric acid and aromatic solvents and should not be used if aliphatic solvents such as gasoline, heptane, or naphtha are likely to contact the membrane. CSPE is subject to attack by aromatic solvents such as benzene or toluene but is more resistant than CPE to aliphatics. PIB, on the other hand, is subject to attack by both aromatic and aliphatic solvents, as well as fats, oils, and direct exposure to coal tar. For these reasons, it is advisable to consult the membrane manufacturers if exposure to any contaminating substance is possible. One of the most likely sources of such contamination on military installations is oil leaking or spilling from mechanical equipment on the roof, particularly air conditioning equipment. Another likely source is exhaust from hoods in kitchens and galleys which may contain high concentrations of cooking fats and oils.

One contaminant which may attack these roofing materials has not been mentioned in the manufacturers' literature. Under certain circumstances there may be a large and continuously increasing deposit of bird droppings. As this material decomposes, the concentration of cyclic and straight-chain organic compounds can increase. The longterm effects of such exposure have not been studied.

Because of the tendency of CPE and CSPE to cure after installation, repairing damages after a lapse of time may be difficult or impossible. One manufacturer requires cleaning, treatment with solvent, priming, and use of a pressure-sensitive adhesive. These operations may be beyond the skill of the typical workman, especially one who is used to repairing any roof leak by trowelling on some plastic bituminous cement.

CPE and CSPE also have a tendency for high shrinkage, in some cases much more than the 1 percent maximum claimed by the manufacturers (Table 1).¹³

¹³Private communication, M. J. Rosenfield with Simpson, Gumpertz and Heger Inc., May 1985; Private communication, M. J. Rosenfield with H. B. Fishman & Co., Inc., July 1985.

This shrinkage was determined to be the cause of splits in one CPE membrane.¹⁴

In another case, a CSPE installation, the presence of ponded water and heavy algae growth seemed to contribute to the shrinkage, which completed damage caused by partial penetrations during installation, causing them to propagate completely through the membrane. This shrinkage also pulled the membrane away from perimeter walls and out of the reglets, which were 10 in. (254 mm) above the deck.¹⁵

Rapid curing of CSPE may make it difficult or impossible to complete an installation. Some mechanically fastened systems require separate cover strips to be welded over the fasteners. In one reported case, the material cured so rapidly that the covers could not be installed, even when the manufacturer's directions were followed carefully.¹⁶

No such negative information has been received about PIB roofing.

4 INSTALLATION METHODS

Loose Laid and Ballasted

While uncured elastomers can be installed in this way, not all manufacturers recommend it for their products. Each manufacturer has specific requirements for size, quantity, and distribution of ballast for its own systems, and these recommendations should be followed. At the time of this writing, the International Conference of Building Officials (ICBO) was considering uniform recommendations for ballast application, but it is not known when these will be forthcoming. As with other loose-laid systems, the following factors must be carefully considered:

- Loose-laid and ballasted systems in areas subject to high winds either should not be used or must be carefully designed. Even the presence of parapets may not prevent displacement of the ballast followed by subsequent ballooning and tear-off of the membrane.

¹⁴Private communication, M. J. Rosenfield with Simpson, Gumpertz and Heger Inc., May 1985.

¹⁵Private communication, M. J. Rosenfield with Hawaiian Dredging & Construction Co., July 1985.

¹⁶Private communication, M. J. Rosenfield with H. B. Fishman & Co., Inc., July 1985.

- The physical condition of the ballast available in the local geographic area is important. Ballast should be free of excessive flat faces, sharp edges and corners, and fines. If the only ballast available is crushed rock, such as granite or flint, a ballasted system should not be used, because the membrane may be punctured or cut.

- Construction of the roof deck and supporting structure must be adequate to support the dead load of the ballast and still have enough live or snow load capacity to satisfy local requirements. Special attention should be given to the possibility of drifting snow. A study by the National Research Council of Canada¹⁷ shows that a larger size stone is necessary as wind speed increases. If complete coverage with larger stones is desired, the weight per unit area must be increased until a point is reached where the entire allowable live load could be consumed by the ballast, and the structure may even be in danger of collapsing. This condition is especially possible when reroofing an old building. Building design and deck capacity must be carefully reviewed by a competent structural engineer if a ballasted system is contemplated.

Mechanically Fastened

Only mechanical fastening of uncured elastomeric membranes is recommended by all the manufacturers of reinforced CPE and CSPE. These products lend themselves to this method of application because of the high resistance of the reinforcing fabric to tearing where the fastener penetrates the membrane. In each case the fasteners are installed along one edge of the sheet and covered with the edge of the next sheet, which is then welded to the first sheet forming the lap seam. One manufacturer of 72 in. (1.83 m) wide sheeting recommends an additional row of fasteners down the center of the sheet, with each fastener covered by a welded-on patch of membrane material. Fastener spacing depends on deck type as well as anticipated wind conditions. Individual manufacturers should be consulted for recommendations for fastening requirements, as each has a different corner and perimeter treatment. No standard fastener plate or washer is used for sheet hold-downs. Some manufacturers use a 2 in. (51 mm) square plate with pressed ribs, others use a 1-1/2 × 2-3/4 in. (38 × 70 mm) flat rectangular plate. Each has a countersunk recess at its center for the head of the fastening screw, and each has rounded corners.

¹⁷R. J. Kind, and R. W. Wardlaw, *Design of Rooftops Against Gravel Blow-Off*, NRC No. 15544 (National Research Council of Canada, Ottawa, ONT, September 1976).

Partially Adhered

Partial adherence is used only for PIB membranes, which were initially developed to be installed by this method. As stated previously, the adhesive used with PIB is type III or IV asphalt, applied by moving the top in a serpentine fashion. The membrane is immediately unrolled into the molten bitumen. Ideally, the asphalt should cover 50 percent of the deck area, as stated in the manufacturer's instructions, but this may be difficult to achieve. As the PIB is backed with a polyester fleece which does not provide reinforcement, its low modulus permits it to conform to substrate movement without tearing and still remain flat.

Fully Adhered

All three uncured elastomeric materials are offered as fully adhered systems, although not by all suppliers of each material. CSPE is usually laid in a water-based latex adhesive, although a contact adhesive may be used at temperatures too low for the latex. One CPE manufacturer permits the membrane to be adhered with either asphalt or adhesive, while asphalt is used for PIB. The CSPE should be applied to the latex adhesive while it is still wet, although tack-free surface dryness is acceptable in some instances. Individual manufacturer's instructions should be consulted for specific recommendations. Regardless of the type of adhesive used, all air pockets must be removed while laying the membrane, by brushing, rolling, or other recommended method. The designer also should consider the possibility of loss of adhesion due to condensation of moisture; this may soften the adhesive or affect the surface of the substrate, causing delamination of paper-faced insulation, softening of fiberboard, or dissolving of binders in fiberglass insulation.

5 USING UNCURED ELASTOMERIC SYSTEMS

Reroofing

Most single-ply systems are used in reroofing applications. If the old roof, presumably a BUR, is largely undeteriorated, only minimal preparation is necessary. Blisters may have to be cut out, gravel swept off, and a recover board fastened to the surface. However, complete removal of the old system should always be seriously considered whenever reroofing is being planned. If insulation is wet, the entire roofing system must be removed. Removal is also recommended if the deck needs repair or maintenance, or if the roofing

system has deteriorated to the point it can no longer serve even as a substrate for a new system. If the building had been reroofed in the past by superimposing a second system above the first, then all the old materials should be completely removed.

New Construction¹⁸

The decision on whether to use a single-ply system instead of the traditional BUR for new construction often depends greatly on relative costs. On the average, a single-ply system costs about 10 percent more than BUR, but there are certain trade-offs:

- If the roof is on a very high building, it is difficult to deliver the hot bitumen and to maintain it at the proper temperature. Because single-ply sheets are easier to handle, the overall labor costs should be lower. However, the installation of a system which uses asphalt as an adhesive, such as PIB, may not be indicated in such a situation. High winds should be considered when choosing a roofing system.

- On a large, flat roof, built-up material is less expensive. The difference in costs should decrease in the future, however, if both labor and materials costs increase.

- While the initial installation cost is less for a BUR, maintenance costs on a poorly designed or installed BUR might even out this difference in 3 or 4 years. In 8 to 10 years, a BUR could cost about one-third more than a relatively lower-maintenance single-ply roof.

Flashing and Sealing

Flashings are used to seal all terminations, penetrations, and interruptions of the roofing membrane. This function is commonly thought of in terms of preventing water penetration. For loose-laid and mechanically fastened single-ply systems, the flashings must also be designed to prevent wind penetration. Some details are reproduced in the Appendix, where a few of the manufacturers may be compared.

Flat Vertical Surfaces and Roof Edges

There is no industry standard for flashing. Some manufacturers use elastomer-coated sheet metal bent to shape, to which the membrane can be solvent or heat welded. Others use either the roofing membrane itself, or with a separate strip of membrane covering

the joint with the coated sheet metal. Some extend the membrane down over the edge of the roof and fasten it to the nailer with the continuous cleat. Others make no such provision for termination. Although all manufacturers require the installation of treated wood nailers, there is no industry-wide standard for the strength of attachment of the nailers to the building structure. Nailers are intended to secure flashings against wind loads and to restrain shrinkage, and both possibilities should be considered. Some manufacturers specify 75 lb/ft (1095 N/m) pullout resistance, while others specify 175 lb/ft (2560 N/m). Claimed shrinkage values are between 0.1 and 1 percent. Most membranes are installed fully adhered or mechanically fastened, and most of the loads induced by shrinkage will not be transmitted to the nailers. Expansion joints in the sheet metal are usually made by leaving a gap between ends of the sections, covering the gap with tape or kraft paper as a slip sheet, and then welding a wider piece of membrane to cover the joint. There may or may not be a backing plate beneath the flashing. As the roof membrane is welded on top of this strip and the sheet metal flange, careful attention must be given to preparing and sealing the junction where all these surfaces meet. The edge of the sheet metal where the roof membrane is attached is usually a sheared edge. Even though the direction of shearing is down, this edge may be sharp. However, none of the manufacturers recommends that this edge be turned under to provide a hem edge before the membrane is attached.

Corners

There is no industry standard for flashing of corners. Some manufacturers describe a method of forming corner flashings from membrane materials in their installation instructions. Others provide prefabricated single-piece corner flashings, while still others make no mention of this detail. In any case, the corner must be flashed very carefully if the joint is to be waterproof.

Pipes and Conduits

Unlike manufacturers of cured elastomers, manufacturers of uncured elastomeric roofing do not furnish prefabricated pipe sleeves for flashing plumbing vents and other pipes or electrical conduits which penetrate the roof. Pipe flashing with these materials is basically a two-piece installation. A flat flange piece of unreinforced membrane is cut in a large circle or square, and a hole two-thirds the size of the pipe is cut in its center. This is fitted down onto the pipe, rising up a short distance like a collar. A reinforced or unreinforced piece of membrane material is then wrapped

¹⁸M. J. Rosenfield, *An Evaluation of Polyvinyl Chloride (PVC) Single-Ply Membrane Roofing Systems*.

around the pipe and welded to the collar. Details differ among the systems. Some cement the wrapped piece to the pipe, others do not. Some wrap the first and apply the flanged collar above it, others apply the collar first. Some caulk the top with sealant, others omit this. Some add a draw-band clamp at the top of the wrapped sleeve, others do not. One manufacturer shows a one-piece flashing detail, which is not included in the Appendix. It is not clear from either the detail or the literature if this item is prefabricated or made on the job. Only two of the manufacturers surveyed in this investigation show a detail for flashing a hot pipe or stack. Their details are not similar and it is obvious that neither detail is applicable to all situations. The expertise of the architect or engineer who designs the system is important in determining how well these flashings perform.

Seams

Thermoplastic materials can be fused or welded together by heat welding or use of a solvent. The universal method of heating is with a hot-air gun. Solvent is usually applied with a brush. These methods are used for CPE and CSPE. The PIB is self-seaming. A release paper covers the specially treated edge of the sheet, and the seam is formed by removing the paper and pressing the surfaces together. For end laps of PIB sheets and other joining, a solvent-containing paste is used as an adhesive for narrow widths of unbacked material. End laps should always be staggered so that no more than three layers ever exist at any joint.

Most manufacturers of CPE and CSPE specify use of a seam caulk at lap edges to prevent water from wicking into the reinforcement. Some manufacturers extend the elastomer beyond the edge of the reinforcement along the seaming edge of the sheet, so that the reinforcement is encapsulated, eliminating the need for caulk. Caulking is necessary along the edge of all flashing and cut sheet joints, as the reinforcement is always exposed. The PIB, however, being unreinforced, does not require caulk along the edges. The technique for forming seams with the automatic heat-welding machine is critical and is extremely sensitive to variations in hot air temperature and machine speed. At slow machine speeds, which produce the hottest welding environment, the membrane material can start to boil and pinhole, resulting in laps that are full of blisters and ridges. At a speed which produces the strongest thermally welded laps, there can still be some heat damage and pinholing. Faster machine speeds may not yield adequate thermal bonding as the lap may not be heated long enough to

produce the required joint. Lap edge sealant, if used, may either split or become unbonded from the edge of the sheet, allowing water to contact the reinforcement or penetrate a poorly bonded lap seam.¹⁹

Insulation Restrictions

With certain restrictions, all common types of insulation boards can be used with the uncured elastomeric membranes. In some cases a separation or cushioning layer may be required; in others the insulation may not be compatible with the substrate, such as polystyrene board over an old coal-tar roof. Most manufacturers, however, require that they provide written approval for application of the membrane to the selected insulation board. For this reason, the membrane manufacturer should be consulted before insulation is approved for use. This is best accomplished by requiring the contractor to submit the manufacturer's approval before ordering any material. The roof designer should bear in mind at all times that a coordinated system is being assembled, not parts chosen at random from what is available on the open market.

Repair Methods

Repairs are not normally necessary for several years after installation, so it is important to know the condition of the membrane at the time repairs are required. CPE and PIB are claimed by the manufacturers not to cure, but to remain in the thermoplastic state indefinitely. Interviews conducted for this study indicate that this claim is open to question, but if it is true, the membrane should be able to be patched in a manner similar to the installation of new material. However, preparation of the surface is extremely important. Dirt or other contaminants must be removed by scrubbing with a brush and detergent or other means. Surface oxidation may have to be abraded away so that cementing or welding can proceed.

CSPE is designed to cure as time elapses, so repair methods for this material are different from those for new installation. One CSPE manufacturer recommends the use of a special solvent to treat the surface before welding can proceed, but this is for installation of material which may have only partially cured. For fully cured material, use of a contact cement may be the only recourse. It may be necessary to try several methods before a successful one is determined. In each case, the original manufacturer should be consulted for

¹⁹Private communication, M. J. Rosenfield with Simpson, Gumpertz and Heger Inc., May 1985.

suggestions and assistance, bearing in mind that a roof that cannot be repaired when damaged must be replaced as soon as possible.

6 CONCLUSIONS AND RECOMMENDATIONS

The physical and mechanical properties of various types of CPE, CSPE, and PIB membrane materials are compared in Table 1. Based on a survey of literature, manufacturers, and field applications of these three uncured elastomeric membrane materials, the following advantages were determined:

1. High strength.
2. Resistance to most common chemicals, ozone, sunlight attack; can be used in wide range of climates and environments.
3. Adaptability to several methods of installation.

Disadvantages of the materials are:

1. CPE is susceptible to nitric acid, aromatic solvents, and aliphatic solvents; CSPE is subject to attack

by aromatic solvents; and PIB is subject to attack by aromatic and aliphatic solvents, as well as fats, oils, and direct exposure to coal tar. Bird droppings may also present a problem.

2. Despite manufacturer's claims to the contrary, CPE tends to cure after installation, which may make subsequent repairs difficult or impossible. CSPE is designed to cure after installation.

3. CPE and CSPE may have a tendency for high shrinkage, which can cause splitting.

4. Rapid curing of CSPE may make it difficult or impossible to complete an installation.

5. Uncured elastomers do not have a long history of use, and there is as yet no industry-wide standard for their manufacture, although ASTM is nearing completion of a draft document. What uniformity there is in these products is due only to the limited number of manufacturers in the market at present.

It is recommended that Corps of Engineers use of CPE, CSPE, and PIB should be delayed until industry-wide standards are put into practice. In addition, results of testing to determine bonding and membrane shrinkage characteristics, planned for the next 2 years, should be taken into consideration before a final decision is made.

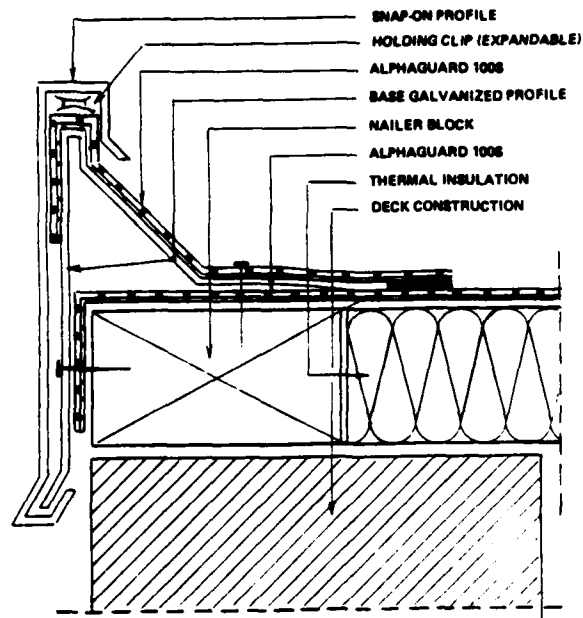
REFERENCES

- ASTM D 412-83, "Standard Test Methods for Rubber Properties in Tension" (American Society for Testing and Materials [ASTM], 1983).
- ASTM D 751-79, "Standard Methods of Testing Coated Fabrics" (ASTM, 1979).
- ASTM D 882-83, "Standard Test Methods for Tensile Properties of Thin Plastic Sheeting" (ASTM, 1983).
- ASTM D 1418-81, "Rubber and Rubber Latices - Nomenclature, Practice For" (ASTM, 1981).
- ASTM D 2262-83, "Standard Method of Tearing Strength of Woven Fabric by the Tongue (Single Rip) Method" (ASTM, 1983).
- Kind, R. J., and Wardlaw, R. L., *Design of Rooftops Against Gravel Blow-Off*, NRC No. 15544 (National Research Council of Canada, Ottawa, ONT, September 1976).
- Marvin, E., et al., *Evaluation of Alternative Reroofing Systems*, Interim Report M-263/ADA071578 (USA-CERL, June 1979).
- Rosenfield, M. J., *An Evaluation of Polyvinyl Chloride (PVC) Single-Ply Membrane Roofing Systems*, Technical Report M-284/ADA097931 (USA-CERL, March 1981).
- Rosenfield, M. J., *Evaluation of Sprayed Polyurethane Foam Roofing and Protective Coatings*, Technical Report M-297/ADA109696 (USA-CERL, November 1981).
- Single-Ply Roofing: A Professional's Guide to Specifications* (Single-Ply Roofing Institute, June 1984).

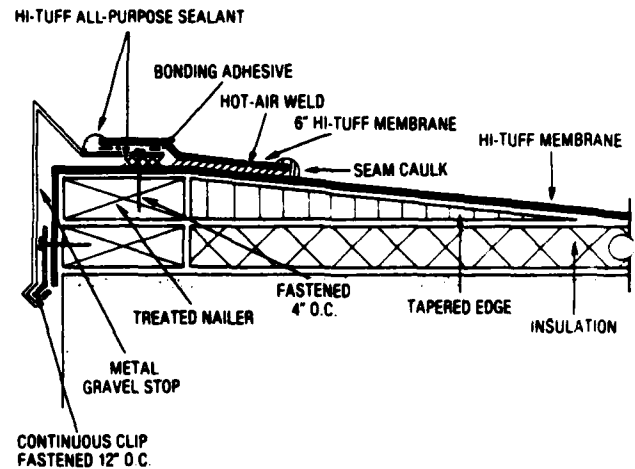
APPENDIX: MANUFACTURERS' DETAILS

This appendix reproduces some standard details published by four of the manufacturers surveyed during this investigation. These drawings have been reduced and grouped onto common pages so they can be compared. If any details are not shown in any

group, it signifies only that the missing manufacturer does not have a published detail for the particular condition. A careful study of these details will reveal the differences and similarities between the various approaches to the same conditions.

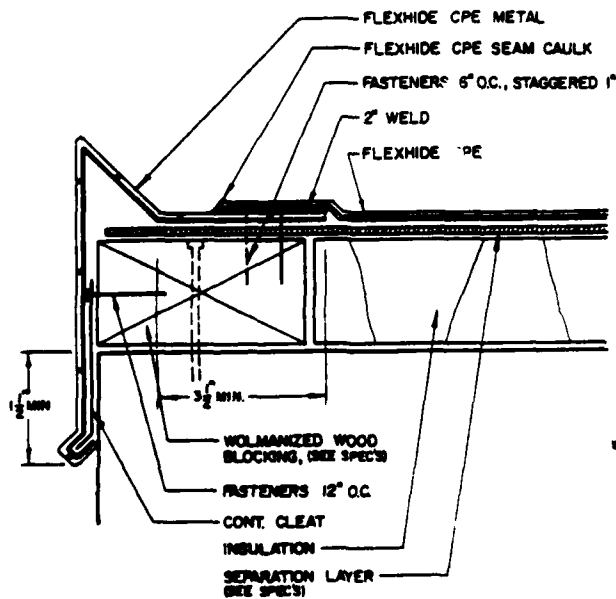


ALPHAGARD ROOFING SYSTEM	Revision	October 1982
ROOF EDGE (NEW ROOF)	Detail No.	1.1



SEE CHART 2 FOR APPROPRIATE GAUGE OF METAL.

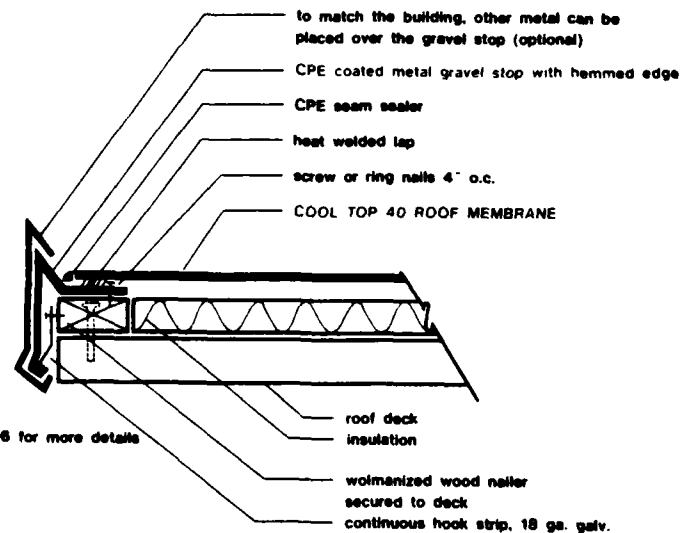
STEVENS	METAL GRAVEL STOP	
Hi-Tuff® Roofing Systems	6-14-84	MF-3



REVISION	DATE	DRAWN BY	APPROVED
ROOF EDGE / RAISED			
DRAWN BY	T.M.	DATE	5-9-84
APPROVED BY	J.C.S.	DWG. NO.	CPE-4

Pantasote

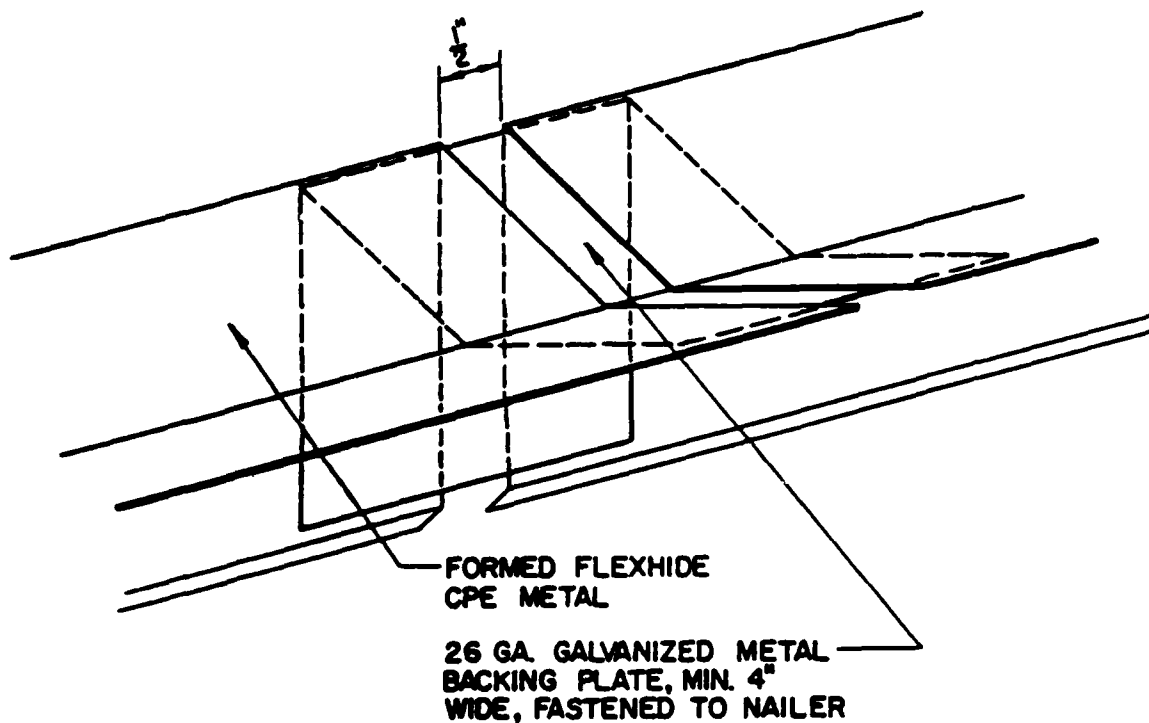
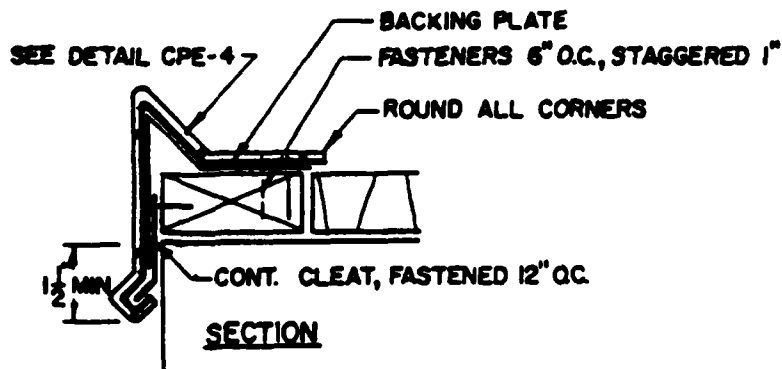
20 JEFFERSON BL., PARSIPPANY, NJ 07054



see dwg. M6 for more details

COOLEY ROOFING SYSTEMS INC.			
Gravel Stop			
system:	MECHANICALLY FASTENED	DWG. DATE	10/1/83
		dwg. no.	M7

Figure A1. Typical gravel stops.

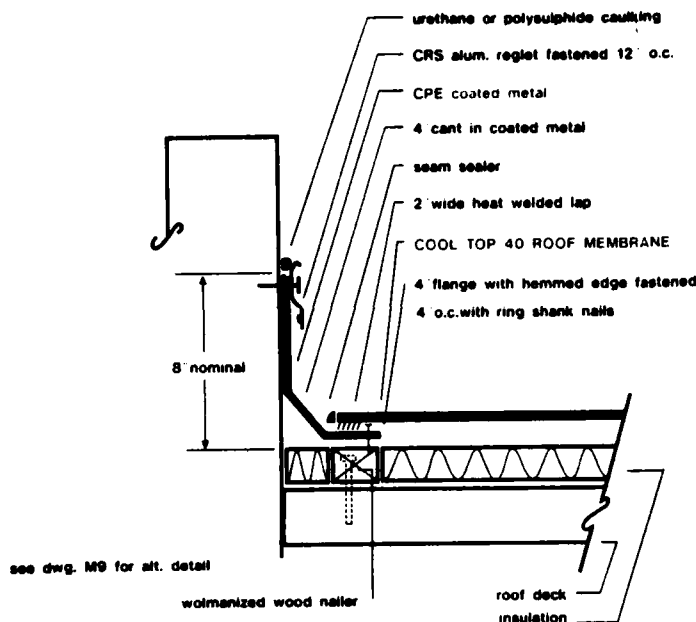


NOTE:

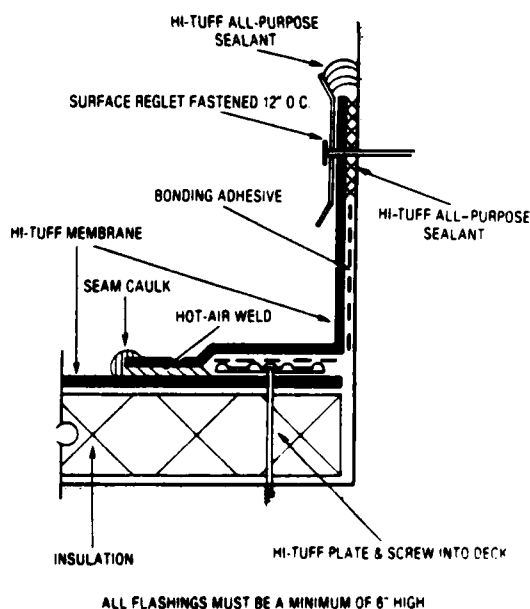
SEE FINISHED ROOF EDGE DETAIL, CPE-9

Pantasote 26 Jefferson St., Passaic, NJ 07065	REVISION	DATE	DRAWN BY	APPROVED BY
	TYP. JOINT/ FLEXHIDE CPE METAL ROOF EDGE			
	DRAWN BY: T.M.		DATE: 3-9-84	
	APPROVED BY: JCS		DRWG No. CPE-8	

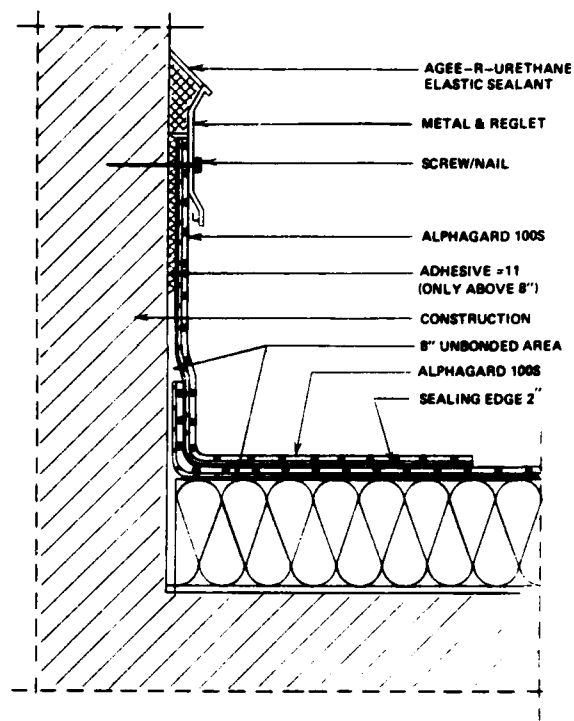
Figure A2. Joints in gravel stops.



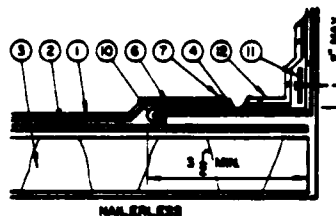
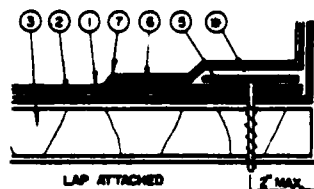
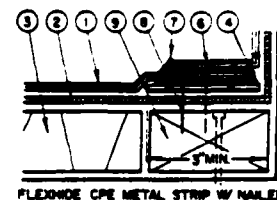
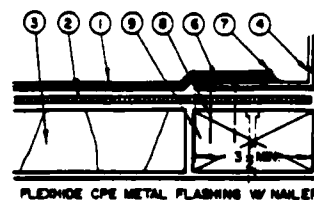
COOLEY ROOFING SYSTEMS INC.			
Parapet Wall Flashing			
system:	MECHANICALLY FASTENED	DWG. DATE	dwg. #
		10/1/83	M10



STEVENS	SURFACE REGLET
Hi-Tuff® Roofing Systems	6-16-84 MF-19



ALPHAGARD ROOFING SYSTEM	Revision	Drawn by
WALL FLASHING		
	Detail No.	



KEY

1. FLENDICE CPE (SEE SPECS)
2. SEPARATION LAYER (SEE SPECS)
3. INSULATION
4. FLENDICE CPE METAL
5. LAP ATTACHED PLATE W/ FASTENER (SEE SPECS)
6. 2" WELD
7. FLENDICE CPE SEAM CAULK
8. FASTENERS 6" O.C., STAGGERED 1"
9. WOOLMANIZED WOOD BLOCKING, SEE SPECS
10. 1" HEM FLANGE
11. 1" METAL WASHER AT BREAK W/ FASTENERS 12" O.C.
12. FLENDICE CPE 45 PATCH, WELD & CAULK
13. WELD BETWEEN FASTENERS AT BASE OF WALL

NOTES

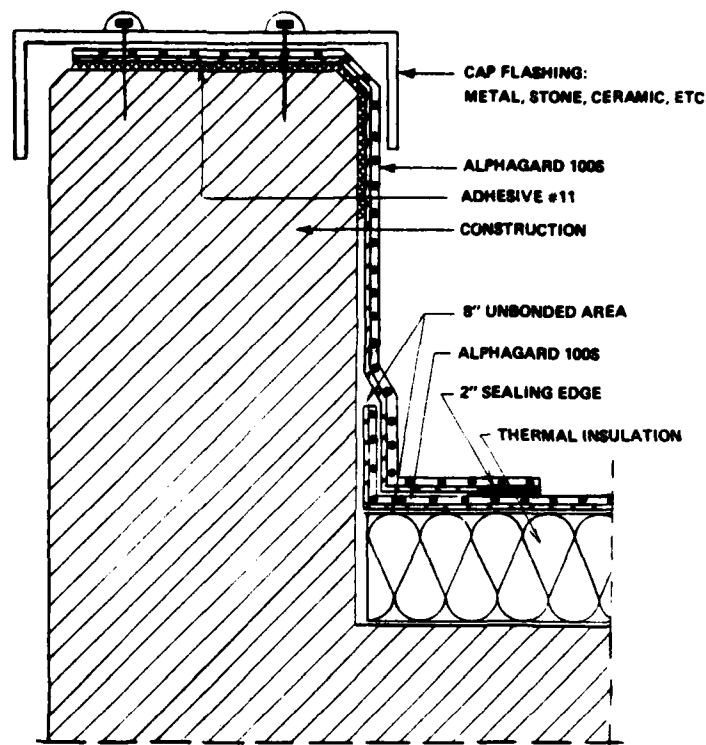
CANT OPTION APPLICABLE ONLY ON FLENDICE CPE METAL FLASHING W/ NAILER

VERTICAL HEIGHT OF BASE FLASHING MIN 6" IF VERTICAL PARTY EXCEEDS 12" CONTACT PANTASOTE FIELD TECH. SERVICE, A.C.S. DIVISION

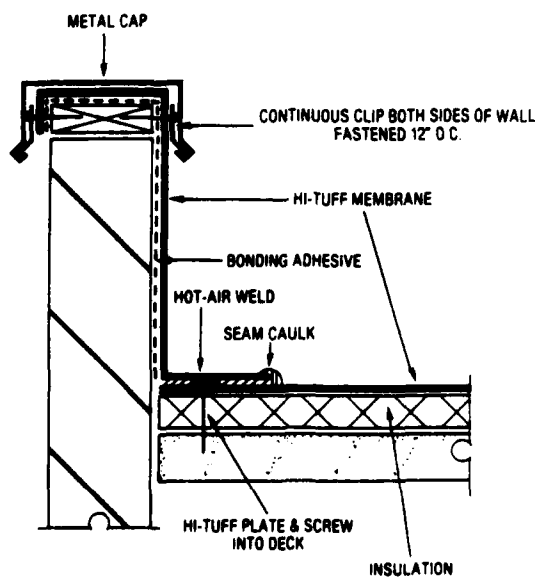
SEE DETAIL CPE-2 OR CPE-3 FOR APPLICABLE COUNTER-FLASHING

REVISION	DATE	DRAWN BY	CHECKED BY
BASE ATTACHMENTS/ FLENDICE CPE			
DRAWN BY T.M.	DATE 3-9-84		
APPROVED BY J.C.S.			

Figure A3. Base flashings at walls.

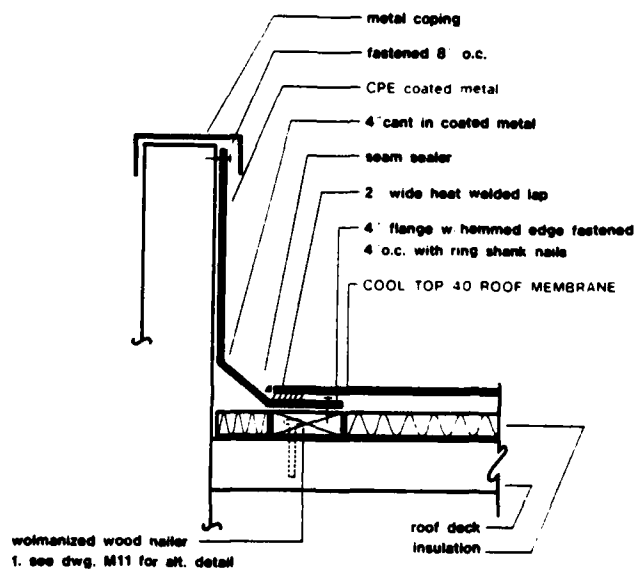


ALPHAGARD ROOFING SYSTEM CAP FLASHING	Revision	October '983
	Detail No.	1/4



ALL FLASHINGS MUST BE A MINIMUM OF 6\"/>

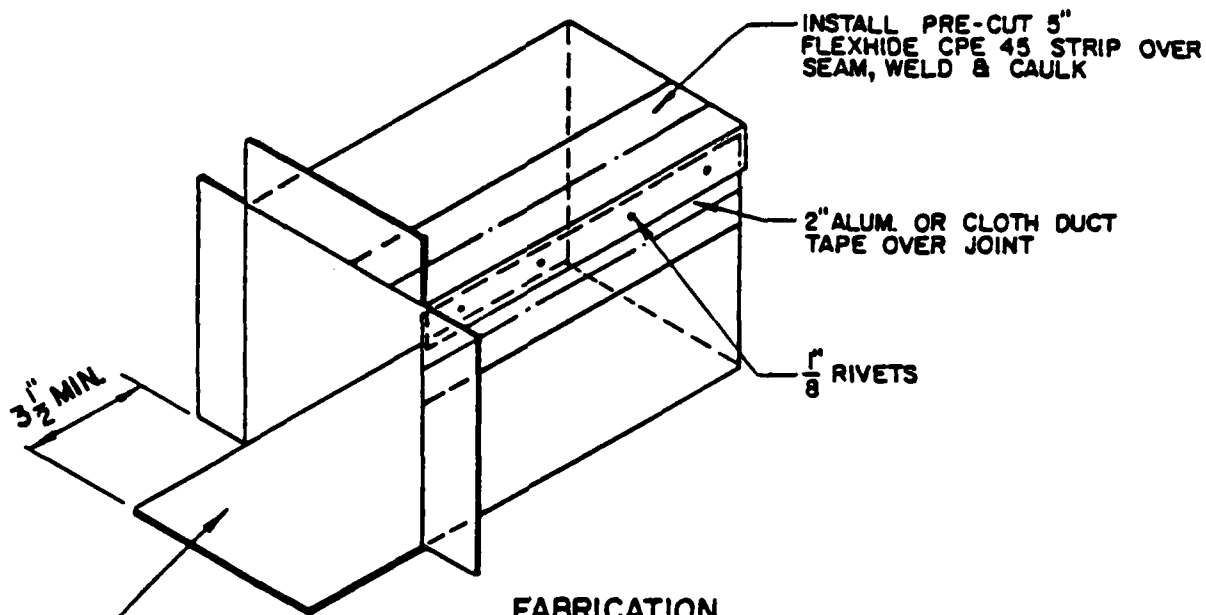
STEVENS Hi-Tuff Roofing Systems	CAP FLASHING TERMINATION	
	9-16-81	MF-21



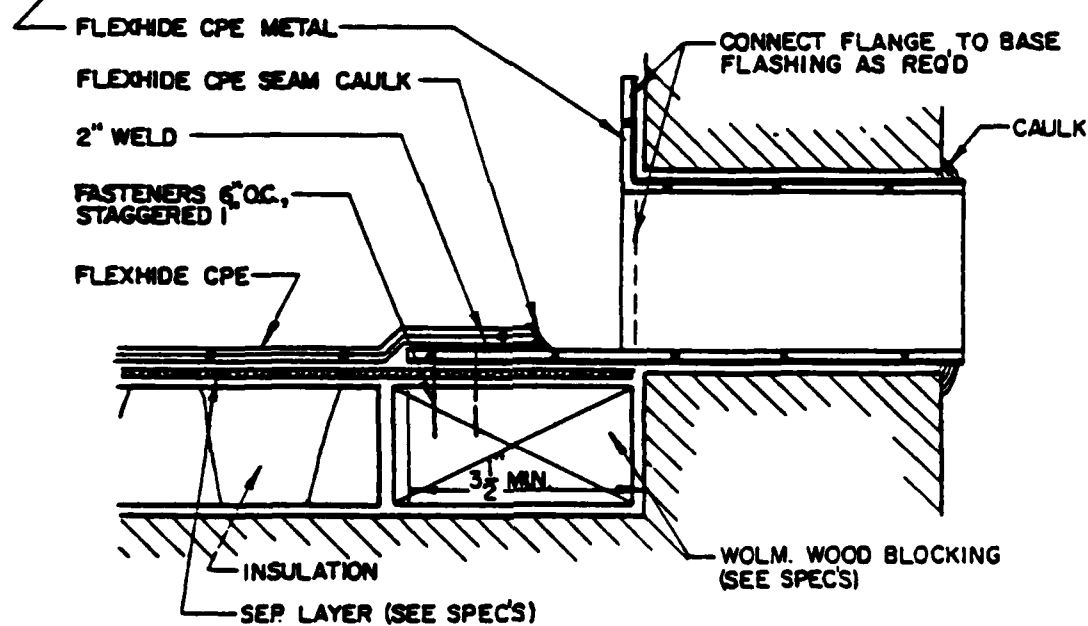
volmanized wood nailer
1. see dwg. M11 for alt. detail

COOLEY ROOFING SYSTEMS INC.			
Parapet Wall Flashing			
system:	MECHANICALLY FASTENED	DWG. DATE	dwg. #
		10 1 83	M12

Figure A4. Base flashings at parapets.



FABRICATION



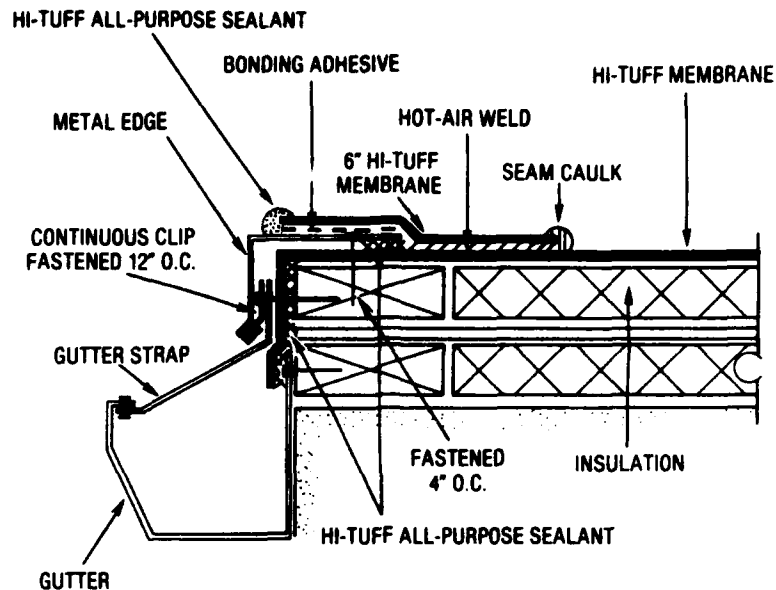
INSTALLATION

Pantasote

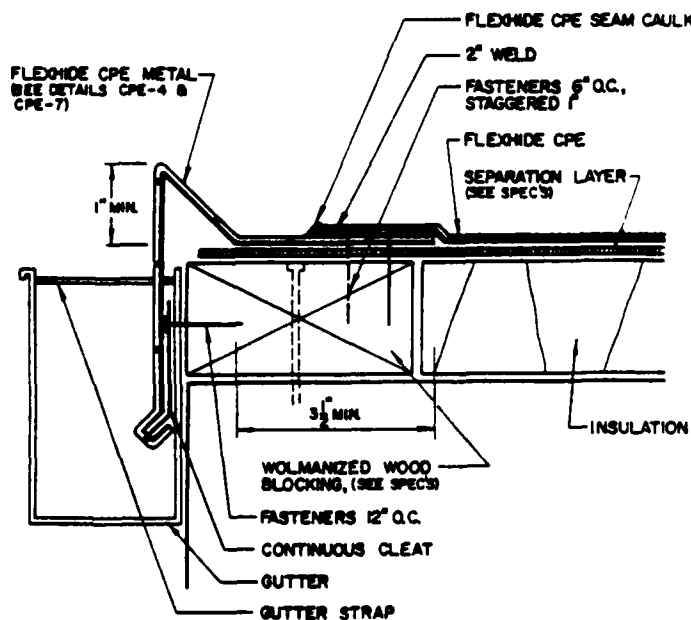
28 Jefferson St., Passaic, NJ 07085

REVISION	DATE	DRAWN BY	APPROVED BY
THRU-WALL SCUPPER (INSTALLATION) (FABRICATION)			
DRAWN BY: T.M.		DATE: 3-9-84	
APPROVED BY: JCS		DRWG No. CPE-26	

Figure A5. Wall scuppers.



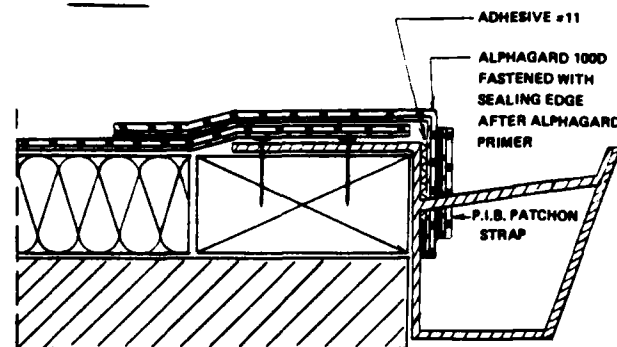
STEVENS Hi-Tuff® Roofing Systems	GUTTER DETAIL "A"	
	6-14-84	MF-7



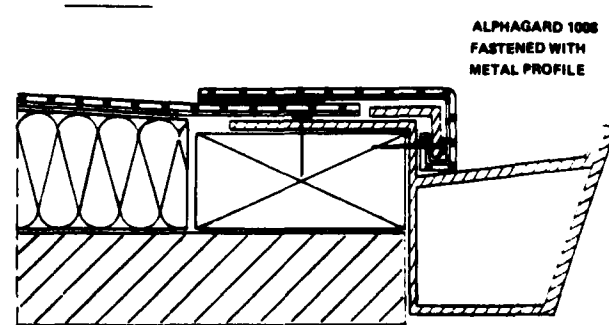
REVISION	DATE	DRAWN BY	APPROVED
ROOF EDGE/ GUTTER			
DRAWN BY	T.M.	DATE	3-9-84
APPROVED BY	JCS	DATE	3-9-84 CPE-8

Pantasote
30 Jefferson St., Passaic, NJ 07650

DETAIL 1

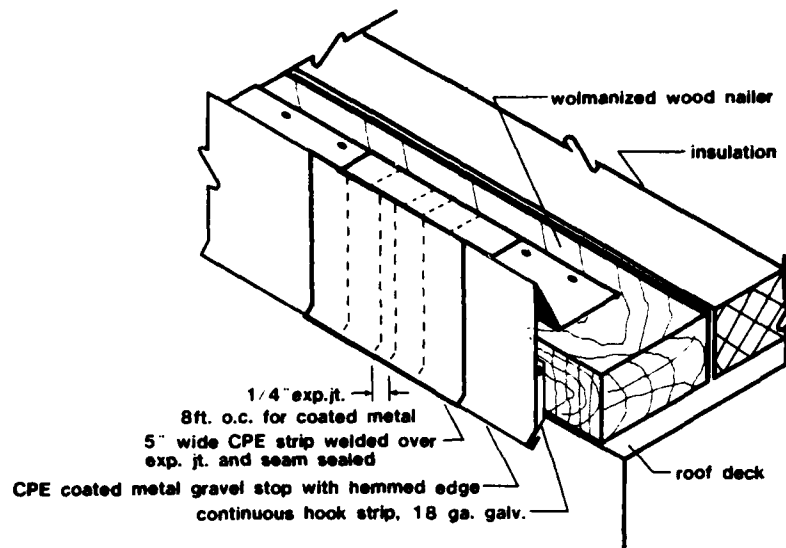


DETAIL 2

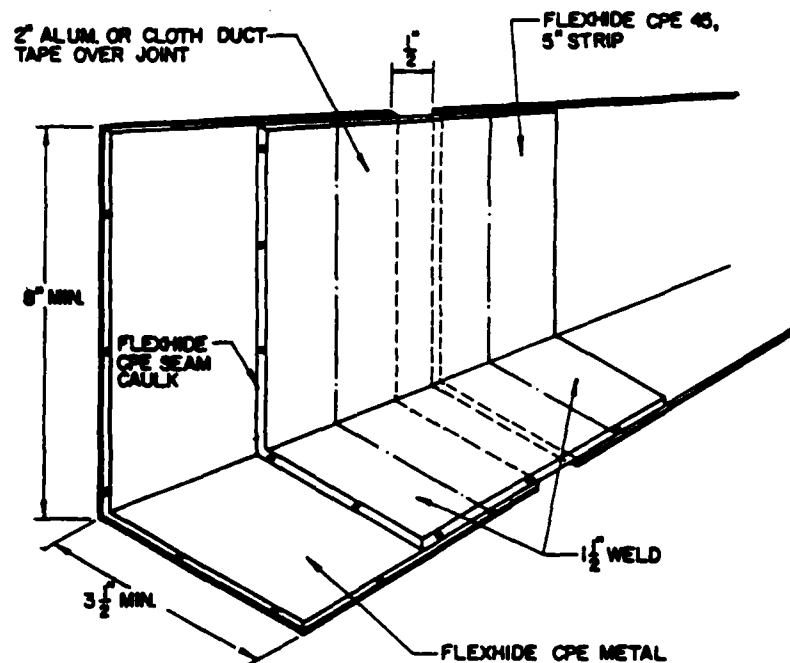


ALPHAGARD ROOFING SYSTEM RAIN GUTTER	Revision	October 1982
	Detail NO	1-9

Figure A6. Gutters.



COOLEY ROOFING SYSTEMS INC.			
Gravel Stop			
system:	MECHANICALLY FASTENED	DWG. DATE	dwg. #
		10/1/83	M6

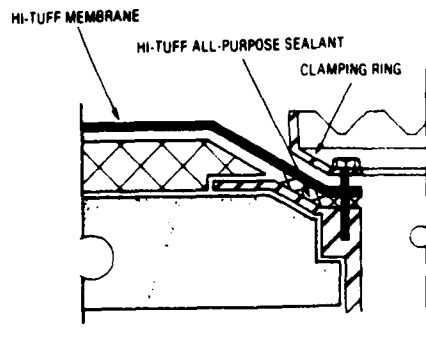


REVISION	DATE	DRAWN BY	APPROVED
BUTT JOINT/ FLEXHIDE CPE METAL BASE FLASHING			
DRAWN BY	T.M.	DATE	3-9-84
APPROVED BY:	CS	DWG. No.	CPE-12

Pantasote

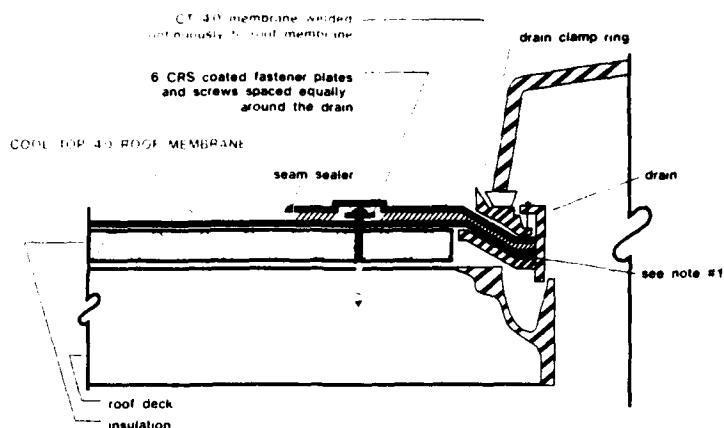
28 Jefferson St., Passaic, NJ 07656

Figure A7. Typical butt joints.



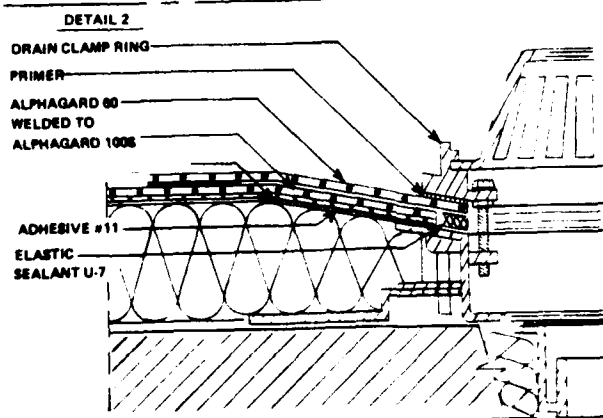
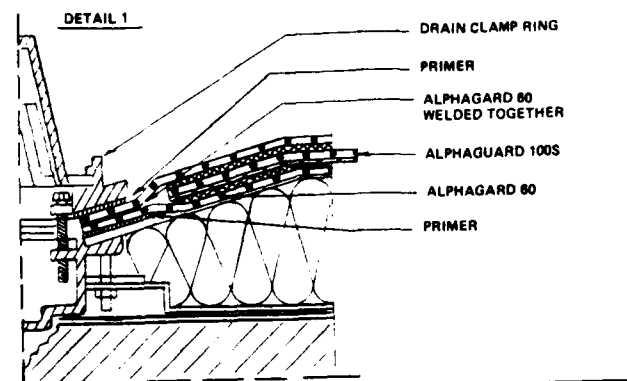
DRAINS MUST HAVE APPROVED CLAMPING RING DETAIL.
DRAIN INSERTS ARE NOT COVERED UNDER WARRANTY

STEVENS	ROOF DRAIN	
Hi-Tuff® Roofing Systems	8-16-84	MF-11

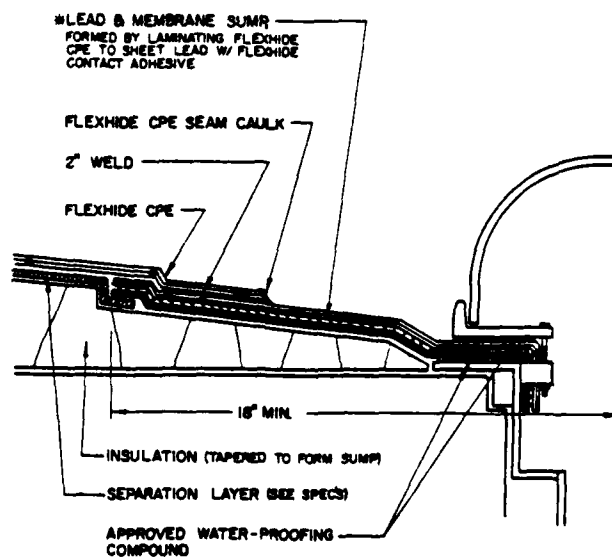


1. set the COOL TOP 40 ROOF MEMBRANE in a wide bead of urethane or polysulphide caulking at the flange of the drain body directly below the clamp ring
2. see dwg M21 for alt. detail suitable for reroofing

COOLEY ROOFING SYSTEMS INC.			
Drain Flashing			
system:	MECHANICALLY FASTENED	DWG. DATE	dwg. #
		10 1 83	M20



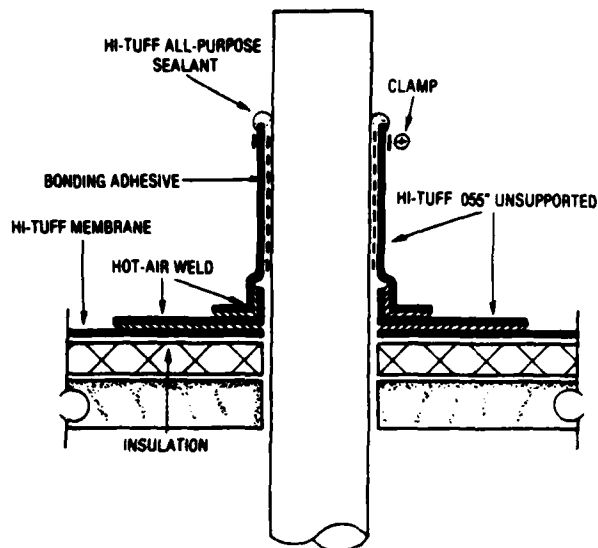
ALPHAGARD ROOFING SYSTEM	Rev. 5-84	Submittal 1
ROOF DRAIN	Detail No.	5



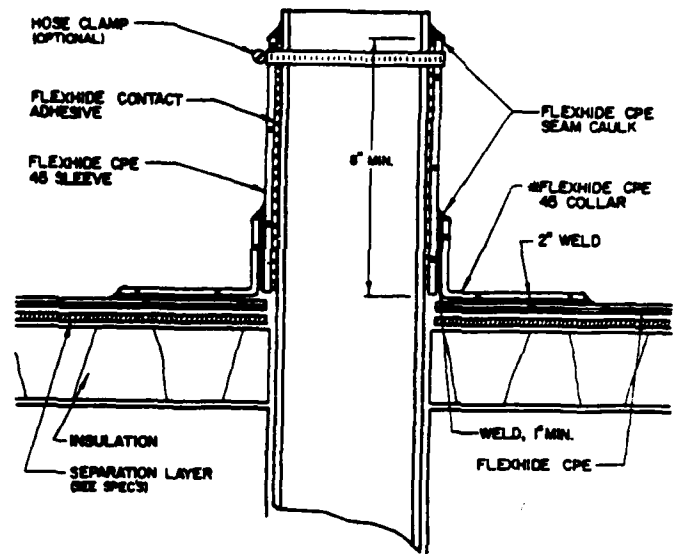
*LEAD SHALL BE WIRE BRUSHED PRIOR TO LAMINATION OF FLEXHIDE CPE

Pantasote			
20 Jefferson St., Phoenix, AZ 85004			
REVISION	DATE	DRAWN BY	APPROVED BY
ROOF DRAIN			
DRAWN BY: T.M.	DATE: 3-9-84		
APPROVED BY: J.C.S.	DWG. NO. CPE-25		

Figure A8. Roof drains.

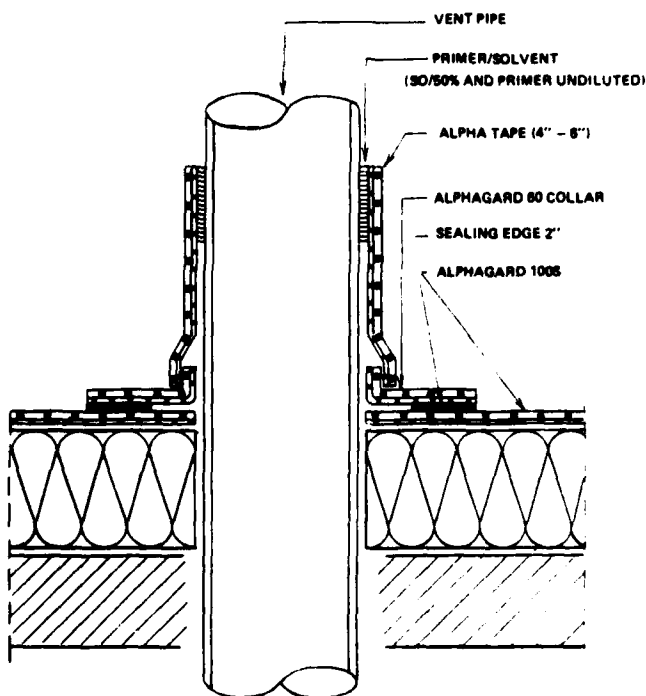


STEVENS	VENT STACK	
Hi-Tuff® Roofing Systems	6-14-84	MF-9

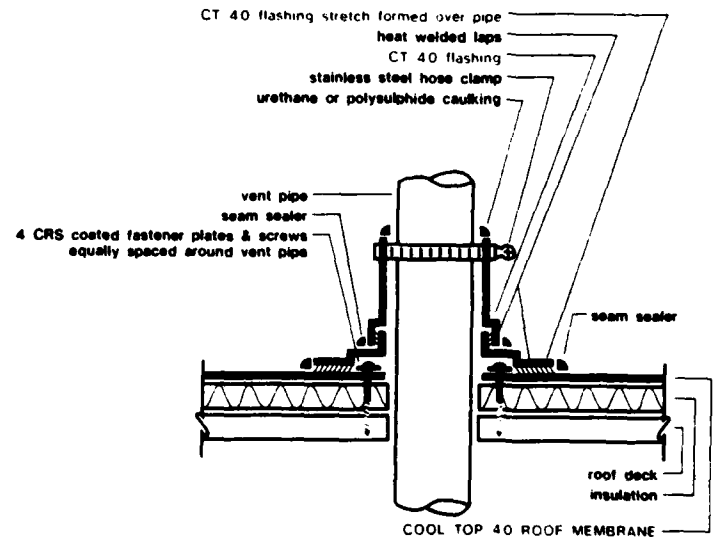


HOLE DIA. OF FLEXHIDE CPE 45
STRETCH COLLAR TO BE
 $\frac{1}{8}$ DIA. OF PIPE

REVISION	DATE	DRAWN BY	APPROVED
Pantasote			
28 Jefferson St., Paramus, NJ 07652			
VENT PIPE / STANDARD			
DRAWN BY T.M.	DATE 3-9-84		
APPROVED BY J.C.S.	DWG NO. CPE-10		

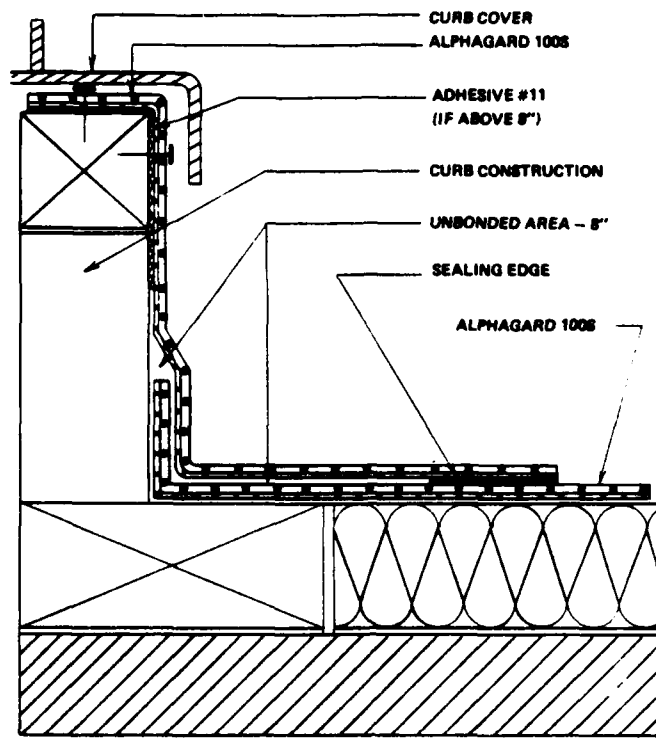


ALPHAGARD ROOFING SYSTEM	Revision	DATE
VENT/PIPE	Detail No.	6

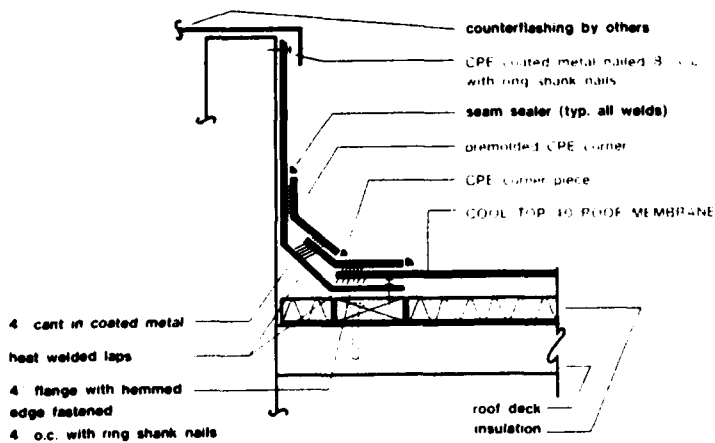


COOLEY ROOFING SYSTEMS INC.			
Vent Pipe Flashing			
system:	MECHANICALLY FASTENED	DWG. DATE	10-1-83
		dwg. no.	M22

Figure A9. Vent pipes.

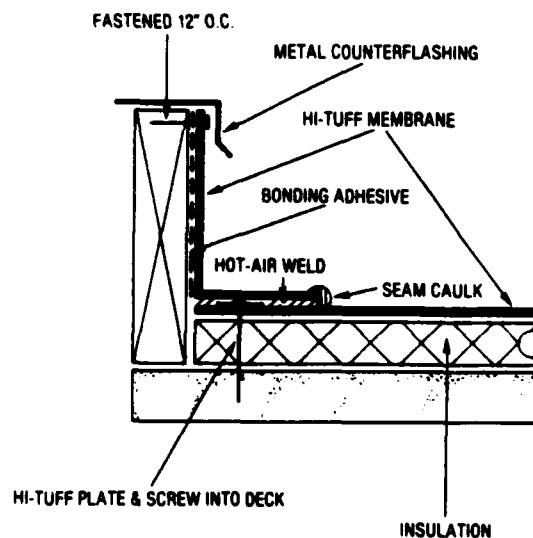


ALPHAGARD ROOFING SYSTEM	Revision October 1983
CURB FLASHING	Detail No. 1/7



SECTION THRU CURB CORNER

1. see dwg. M17 for alt. flashing detail
2. this detail is used when a counterflashing is part of the curb mounted equipment

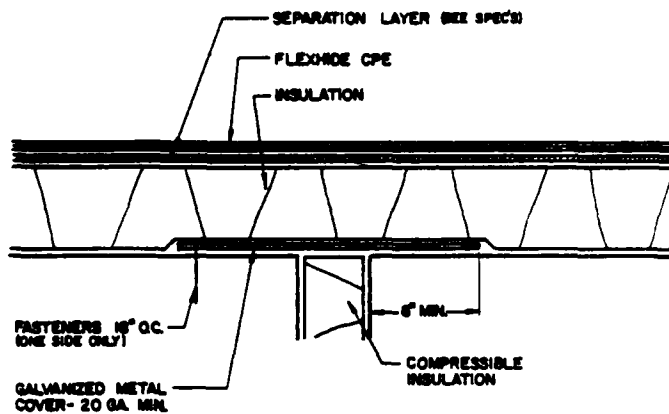


COOLEY ROOFING SYSTEMS INC.			
Roof Curb Flashing			
system:	MECHANICALLY FASTENED	DWG. DATE	dwg. #
		10 1 83	M18

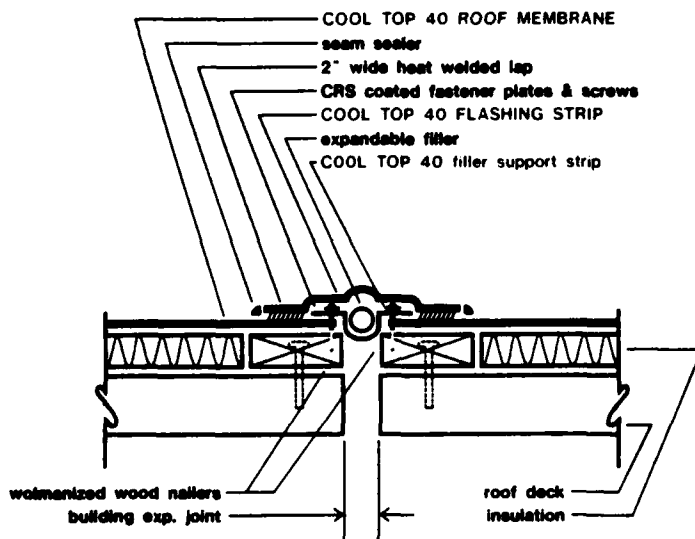
ALL FLASHINGS MUST BE A MINIMUM OF 6" HIGH.

STEVENS	CURB FLASHING "A"	
Hi-Tuff® Roofing Systems	6-14-84	MF-15

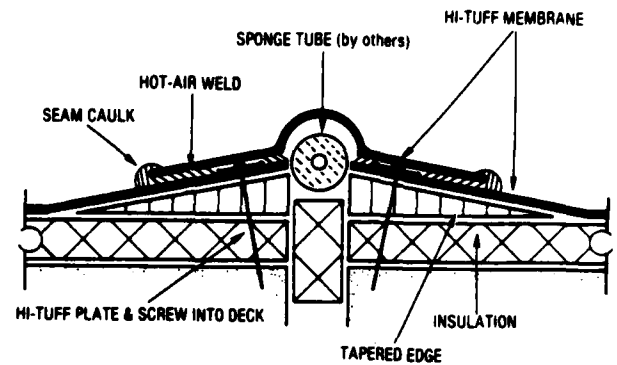
Figure A10. Curb flashings.



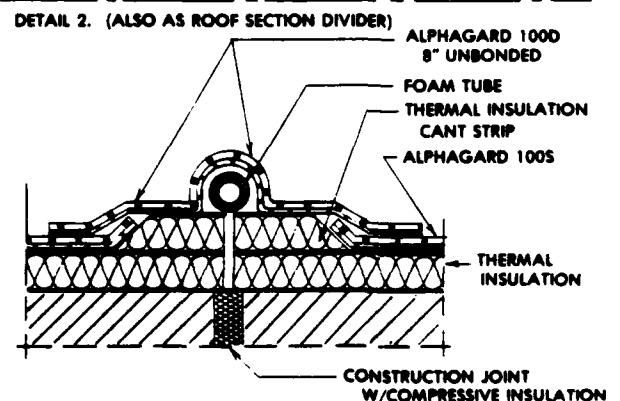
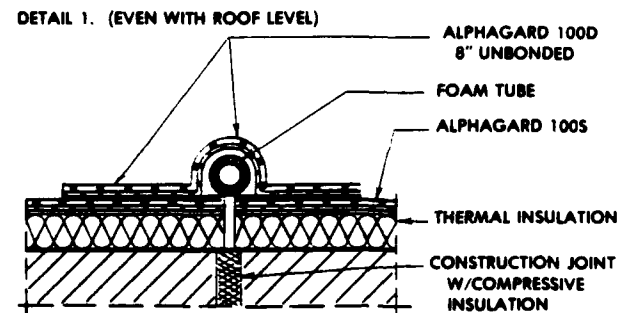
Pantasote		REVISION		DATE	DRAWN BY	APPROVED BY
28 JEFFERSON BL., PARSIPPANY, NJ 07054		EXPANSION JOINT/ IN ROOF				
		DRAWN BY: Y.M.		DATE: 3-8-84		
		APPROVED BY: JCS		CRUS NO: CPE-23		



COOLEY ROOFING SYSTEMS INC.			
Exp. Joint Flashing			
System:	MECHANICALLY FASTENED	SWG. DATE	10/1/83
		SWG. NO.	M15

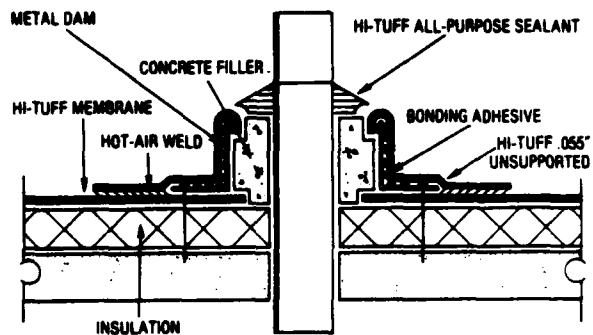


STEVENS		ROOF EXPANSION JOINT	
Hi-Tuff® Roofing Systems		8-16-84	MF-13

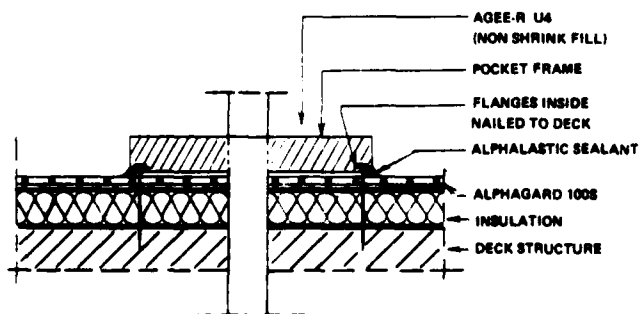
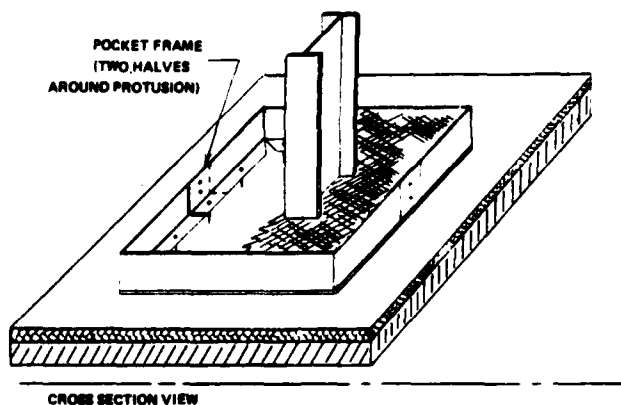


ALPHAGARD ROOFING SYSTEM		Revision	October 84
EXPANSION JOINTS		Detail No.	

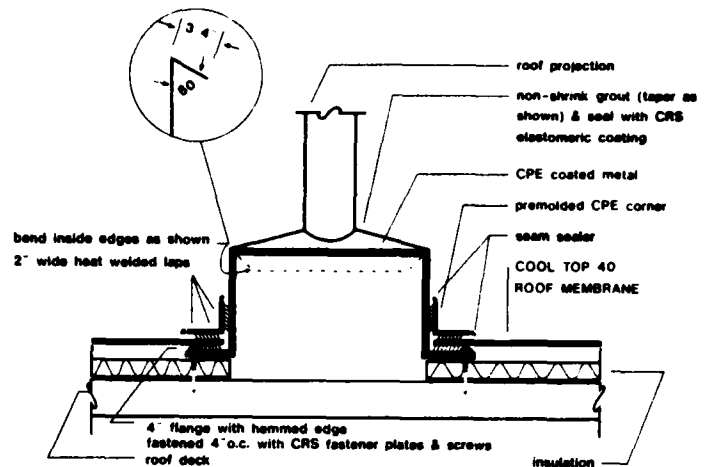
Figure A11. Expansion joints — roof.



STEVENS	PITCH POCKET	
Hi-Tuff® Roofing Systems	8-14-84	MF-12



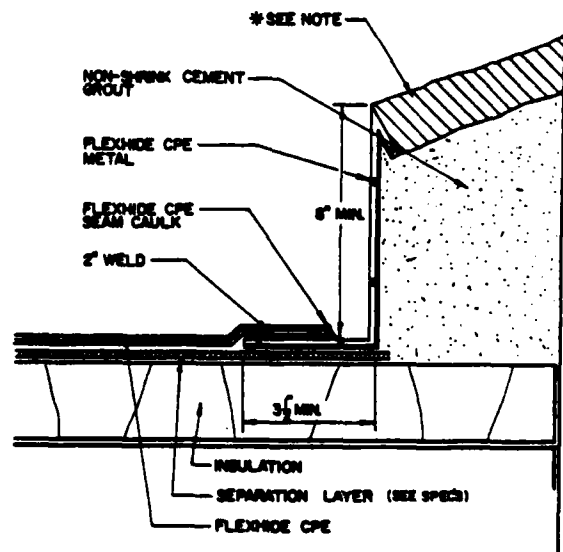
ALPHAGARD ROOFING SYSTEM	Revision	October '84
PITCH POCKET	Detail No.	1-12



NOTE:

1. bend CPE coated metal to form a pitch box as shown
2. allow 2" clearance around the projection (the CPE coated side of the metal is on the outside)
3. mortar may be used instead of non-shrink grout, fill box to within 1" from the top and fill with pourable urethane sealant

COOLEY ROOFING SYSTEMS INC.			
Pitch Box Flashing			
system:	MECHANICALLY FASTENED	DWG. DATE	dwg. #
		3/1/84	M19

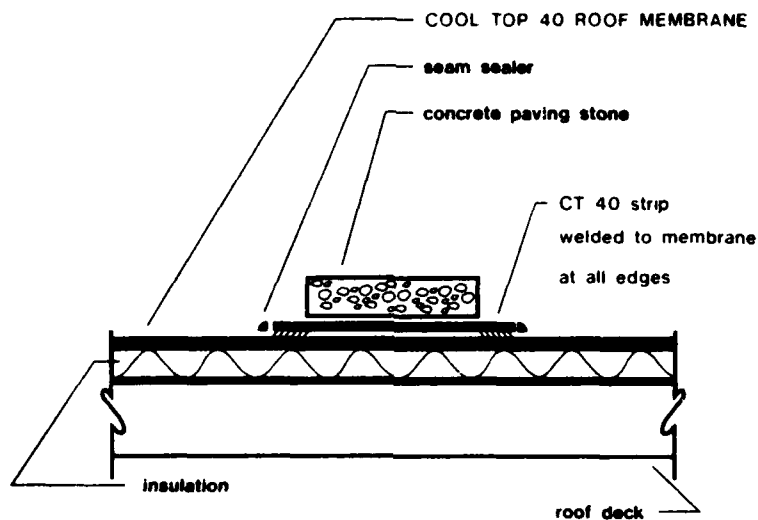


***NOTE**

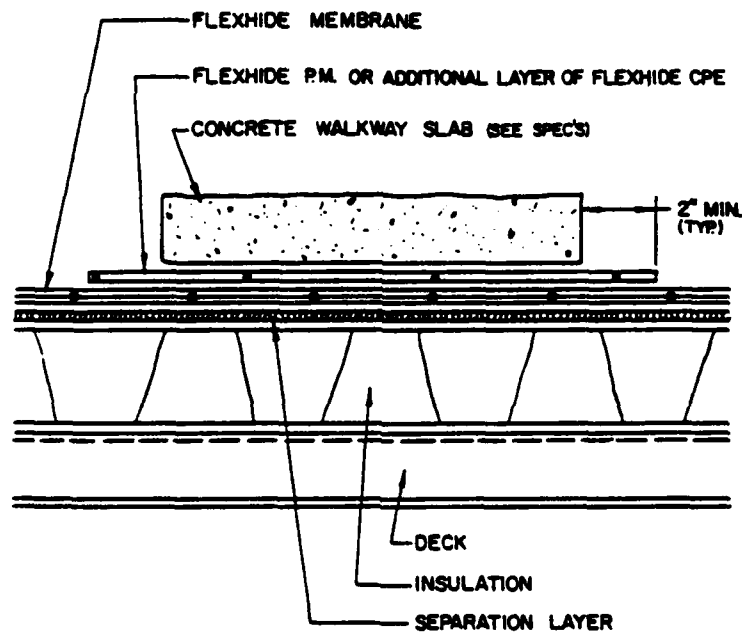
FILL PITCH BOX TO BEND BACK W/ NON-SHRINK GROUT. AFTER GROUT HAS SET, FILL TO TOP W/ APPROVED WATER-PROOFING COMPOUND, FORMING A MOUND TO PREVENT STANDING WATER

REVISION	DATE	DRAWN BY	APPROVED BY
PITCH BOX/ INSTALLATION			
DRAWN BY: T.M.	DATE: 3-9-84		
APPROVED BY: J.C.S.	DATE: CPE-25		

Figure A13. Pitch pockets.



COOLEY ROOFING SYSTEMS INC.		
Rooftop Walkways		
system:	MECHANICALLY FASTENED	DWG. DATE 10/1/83
		dwg. # M5



Pantasote		REVISION	DATE	DRAWN BY	APPROVED
26 Jefferson St., Pomona, NJ 07658		ROOF WALKWAY			
		DRAWN BY T.M.		DATE: 3-9-84	
		APPROVED BY: JCS		DWG. No. CPE-20	

Figure A14. Walkways.

USA-CERL DISTRIBUTION

Chief of Engineers
ATTN: Tech Monitor
ATTN: DAEN-ASI-L (2)
ATTN: DAEN-CCP
ATTN: DAEN-CW
ATTN: DAEN-CWE
ATTN: DAEN-CWN-R
ATTN: DAEN-CWO
ATTN: DAEN-CVP
ATTN: DAEN-EC
ATTN: DAEN-ECC
ATTN: DAEN-ECE
ATTN: DAEN-ECR
ATTN: DAEN-ED
ATTN: DAEN-EDC
ATTN: DAEN-EDM
ATTN: DAEN-EM
ATTN: DAEN-ECE
ATTN: DAEN-ZCF
ATTN: DAEN-ZCI
ATTN: DAEN-ZCM
ATTN: DAEN-ZCZ

FESA, ATTN: Library 22060
ATTN: DET III 79906

US Army Engineer Districts
ATTN: Library (41)

US Army Engineer Divisions
ATTN: Library (14)

US Army Europe
AEAEN-ODCS/Engr 09403
ISAE 09081
V Corps
ATTN: DEN (11)
VII Corps
ATTN: DEN (15)
21st Support Command
ATTN: DEN (12)
USA Berlin
ATTN: DEN (11)
USASSETAF
ATTN: DEN (10)
Allied Command Europe (ACE)
ATTN: DEN (3)

8th USA, Korea (19)

ROK/US Combined Forces Command 96301
ATTN: EUSA-WMC-CFC/Engr

USA Japan (USARJ)
ATTN: AJEN-DEN 96343
ATTN: DEN-Honahu 96343
ATTN: DEN-Okinawa 96331

416th Engineer Command 60623
ATTN: Facilities Engineer

US Military Academy 10966
ATTN: Facilities Engineer
ATTN: Dept of Geography &
Computer Science
ATTN: DSCPER/MAEN-A

AMHRC, ATTN: DRXMR-WK 02172

USA ARBCOM 61299
ATTN: DRCIS-RI-I
ATTN: DRSAR-IS

AMC - Dir., Inst., & Servc
ATTN: DEN (23)

DLA ATTN: DLA-WI 22314

DNA ATTN: NADS 20305

FORSCOM
FORSCOM Engr, ATTN: AFEN-DEN
ATTN: DEN (23)

NSC
ATTN: NSLO-F 78234
ATTN: Facilities Engineer
Fitzsimons AMC 80240
Walter Reed AMC 20012

INSCOM - Ch, Insl. Div
ATTN: Facilities Engineer (3)

MDW, ATTN: DEN (3)

MTMC
ATTN: MTMC-SA 20315
ATTN: Facilities Engineer (3)

NARADCOM, ATTN: DRDMA-F 01760

TARCOM, Fac. Div. 48090

TRADOC
HQ, TRADOC, ATTN: ATEN-DEN
ATTN: DEN (19)

TSARCOM, ATTN: STSAS-F 63120

USACC, ATTN: Facilities Engr (2)

WESTCOM
ATTN: DEN, Ft, Shafter 96858
ATTN: APEN-IM

SHAPE 09055
ATTN: Surv. Section, CCB-OPS
Infrastructure Branch, LANDA

HQ USEUCOM 09128
ATTN: ECJ 4/7-LOE

Fort Belvoir, VA 22070 (7)
ATTN: Canadian Liaison Office
ATTN: Water Resources Support Ctr
ATTN: Engr Studies Center
ATTN: Engr Topographic Lab.
ATTN: ATZA-DTE-SU
ATTN: ATZA-DTE-EM
ATTN: R&D Command

CREEL, ATTN: Library 03755

WES, ATTN: Library 39180

HQ, XVIII Airborne Corps
and Fort Bragg
ATTN: AFZA-FE-EE 28307

Area Engineer, AEDC-Area Office
Arnold Air Force Station, TN 37389

Chanute AFB, IL 61868
3345 CES/DE, Stop 27

Morton AFB, CA 92409
ATTN: AFRCF-MX/DEE

NAVFAC
ATTN: Engineering Command (7)
ATTN: Division Offices (6)
ATTN: Naval Public Works Center (9)
ATTN: Naval School, Morell Library
ATTN: Naval Civil Engr Lab. (3)

NCEL ATTN: Library, Code LOBA 93041

Defense Technical Info. Center 22314
ATTN: DDA (2)

Engr Societies Library, NY 10017

Natl Guard Bureau Insl. Div 20310

US Govt Printing Office 22304
Receiving Sect/Depository Copies (2)

US Army Env. Hygiene Agency
ATTN: HSRB-E 21010

National Bureau of Standards 20760

03/22/85

EMC Team Distribution

Chief of Engineers 20314
ATTN: DAEN-ZCF-R
ATTN: DAEN-ECZ-A
ATTN: DAEN-ECB (2)
ATTN: DAEN-ZCP

US Army Engineer District
New York 10007
ATTN: Chief, Design Br
Pittsburgh 15222
ATTN: Chief, ORPCD
ATTN: Chief, Engr Div
Philadelphia 19106
ATTN: Chief, NAPEN-D
Baltimore 21203
ATTN: Chief, Engr Div
Norfolk 23510
ATTN: Chief, NAOEN-M
ATTN: Chief, NAOEN-D
Huntington 25721
ATTN: Chief, ORHED-F
Wilmington 28401
ATTN: Chief, SAMCO-C
ATTN: Chief, SAMEN-D
Charleston 29402
ATTN: Chief, Engr Div
Savannah 31402
ATTN: Chief, SASAS-L
Jacksonville 32232
ATTN: Const Div
Mobile 36628
ATTN: Chief, SAMEN-D
ATTN: Chief, SAMEN-F
ATTN: Chief, SAMEN
Nashville 37202
ATTN: Chief, ORNED-F
Memphis 38103
ATTN: Chief, Const Div
ATTN: Chief, LMMED-D
Vicksburg 39180
ATTN: Chief, Engr Div
Louisville 40201
ATTN: Chief, Engr Div
Detroit 48231
ATTN: Chief, NCEED-T
St. Paul 55101
ATTN: Chief, ED-D
ATTN: Chief, ED-F
Chicago 60604
ATTN: Chief, NCCCO-C
ATTN: Chief, NCCED-F
Rock Island 61201
ATTN: Chief, Engr Div
ATTN: Chief, NCRED-F
St. Louis 63101
ATTN: Chief, ED-D
Kansas City 64106
ATTN: Chief, Engr Div
Omaha 68102
ATTN: Chief, Engr Div
New Orleans 70160
ATTN: Chief, LMMED-DG
Little Rock 42203
ATTN: Chief, Engr Div
Tulsa 74102
ATTN: Chief, Engr Div
Ft. Worth 76102
ATTN: Chief, SWFED-D
ATTN: Chief, SWFED-F
Galveston 77550
ATTN: Chief, SWGAS-L
ATTN: Chief, SWGCO-C
ATTN: Chief, SWGED-DC
Albuquerque 87103
ATTN: Chief, Engr Div
Los Angeles 90053
ATTN: Chief, SPLED-F
San Francisco 94105
ATTN: Chief, Engr Div
Sacramento 95814
ATTN: Chief, SPKED-D
ATTN: Chief, SPKCO-C
Far East, 96301
ATTN: Chief, Engr Div

US Army Engineer District
Portland 97208
ATTN: Chief, DB-6
ATTN: Chief, FM-1
ATTN: Chief, FM-2
Seattle 98124
ATTN: Chief, NPSCO
ATTN: Chief, NPSEN-FM
ATTN: Chief, EN-DB-ST
Walla Walla 99362
ATTN: Chief, Engr Div
Alaska 99501
ATTN: Chief, NPASA-R

US Army Engineer Division
New England 02154
ATTN: Chief, NEDED-T
ATTN: Laboratory
ATTN: Chief, NEDCO
Middle East (Rear) 22601
ATTN: Chief, MEDED-T
North Atlantic 10007
ATTN: Chief, NADEN
South Atlantic 30303
ATTN: Laboratory
ATTN: Chief, SADEN-TC
ATTN: Chief, SADEN-TS
Huntsville 35807
ATTN: Chief, HNDED-CS
ATTN: Chief, HNDED-M
ATTN: Chief, HNDED-SR
Lower Mississippi 39180
ATTN: Chief, LMVED-G
Ohio River 45201
ATTN: Laboratory
ATTN: Chief, Engr Div
Missouri River 68101
ATTN: Chief, MRDED-G
ATTN: Laboratory
Southwestern 75202
ATTN: Laboratory
ATTN: Chief, SWDED-MA
ATTN: Chief, SWDED-TG
South Pacific 94111
ATTN: Laboratory
Pacific Ocean 96858
ATTN: Chief, Engr Div
ATTN: FM&S Branch
ATTN: Chief, PODED-D
North Pacific 97208
ATTN: Laboratory
ATTN: Chief, Engr Div

6th US Army 94129
ATTN: AFKC-EN

7th US Army 09407
ATTN: AETTM-HRD-EHD

HQ, Combined Field Army (ROK/US) 96358
ATTN: CFAR-EN

HQDA SGRD-EDE 20314

US Army Foreign Science and
Tech Center
ATTN: Charlottesville, VA 22901
ATTN: Far East Office 96328

USA ARRADCOM 07801
ATTN: DRDAR-LCA-OK

HQ, USAMRDC
ATTN: SGRD-PLC
Fort Detrick, MD 21701

West Point, NY 10996
ATTN: Dept of Mechanics
ATTN: Library

Ft. Belvoir, VA 22060
ATTN: ATSE-TD-TL (2)
ATTN: Learning Resource Center
ATTN: British Liaison Officer (5)

Ft. Benning, GA 31905
ATTN: ATZB-FE-EP
ATTN: ATZB-FE-BG

Ft. Clayton Canal Zone 34004
ATTN: DFAE

Ft. Leavenworth, KS 66027
ATTN: ATZLCA-SA

Ft. Lee, VA 23801
ATTN: DRXMC-D (2)

Ft. McPherson, GA 30330
ATTN: AFEN-CD

Ft. Monroe, VA 23651
ATTN: ATEN-AD (3)
ATTN: ATEN-FE-ME
ATTN: ATEN-FE-EN (2)

Ft. Richardson, AK 99505
ATTN: AFZT-FE-E

Rocky Mountain Arsenal 80022
ATTN: SARRM-CO-FEP

USA-WES 39180
ATTN: C/Structures
ATTN: Soils & Pavements Lab

Naval Facilities Engr Command 22332
ATTN: Code 04
ATTN: Code 2013 C

Port Hueneme, CA 93043
ATTN: Morell Library

Commander (Code 2636) 93555
Naval Weapons Center

Bolling AFB, DC 20332
AF/LEEUU

Little Rock AFB
ATTN: 314/DEEE

Patrick AFB, FL 32925
ATTN: XRQ

Tinker AFB, OK 73145
2854 ABG/DEEE

Tyndall AFB, FL 32403
AFESC/TST

Airports and Const Services Dir
Technical Info Reference Center
Ottawa, Ontario, Canada K1A 0N8

Bldg Research Advisory Board 20418

Dept of Transportation Library 20590
Transportation Research Board 20418

Division of Building Research
National Research Council
Ottawa, Ontario, Canada K1A 0R6

National Defense Headquarters
Director General of Construction
Ottawa, Ontario, Canada K1A 0K2

DTIC

END

4-86